land

MDPI

Review

Building Information Modelling (BIM) Capabilities in the Design and Planning of Rural Settlements in China: A Systematic Review

Yu Cao [1], Liyan Huang [2,*], Nur Mardhiyah Aziz [1,*] and Syahrul Nizam Kamaruzzaman [1]

[1] Faculty of Built Environment, University of Malaya, Kuala Lumpur 50603, Malaysia
[2] School of Management, Education District, Suzhou University, Suzhou 234000, China
* Correspondence: s2023690@siswa.um.edu.my (L.H.); nurmardhiyah@um.edu.my (N.M.A.)

Abstract: With rural revitalization being established as the national policy in China, the environmental quality and residential comfort of rural settlements has received widespread attention from the whole society in China. However, due to the over-exploitation of resources and the uneven development between urban and rural in China, the environmental conditions and residential experience in rural settlements in China are still relatively backward. To prompt the environmental quality and residential comfort of rural settlements in China, it is necessary to optimize the planning and design of rural settlements in China. As a multi-function method, Building Information Modeling (BIM) can significantly contribute to the planning and design of rural settlements in China. To optimize the environmental quality and residential experience in rural settlements in China, this study is developed to perform a systematic literature review of the BIM capabilities in the design and planning phase of rural settlements in China. To achieve this aim, the PRISMA protocol was used to perform this systematic review. The review and discussion of this study were conducted between June 2022 and September 2022. In this study, Web of Science (WoS) and Scopus were adopted as the main databases, and 189 articles were reviewed. Through this systematic review, it can be identified that BIM capabilities have significant advantages in the following aspects of the design and planning of rural settlements in China: Data storage and management; 3D modeling and visualization; Disaster prevention and environmental analysis; Cost estimation and optimization. Furthermore, through the discussion and analysis of research results, it can be concluded that BIM capabilities can perform their benefits in the rural settlements' design and planning through their following characteristics: knowledge management, simulation, and modeling. Based on the research results, it can be identified that knowledge management capabilities in BIM can effectively provide information support and knowledge assistance throughout the design and planning phase of rural settlements in China. BIM's simulation and modeling capabilities can simulate and demonstrate the rural environment and their internal structures in rural settlements' design and planning phase to achieve their environmental optimization, residential comfort improvement, clash detection, disaster prevention, and expenditure reduction. Moreover, the challenge and future directions of BIM capabilities in the design and planning phase of rural settlements in China are discussed and analyzed. This study can effectively promote and optimize the BIM utilization in the design and planning phase of rural settlements in China, to better enhance their environmental quality and residential experience.

Keywords: Building Information Modeling; rural settlements; rural revitalization

check for updates

Citation: Cao, Y.; Huang, L.; Aziz, N.M.; Kamaruzzaman, S.N. Building Information Modelling (BIM) Capabilities in the Design and Planning of Rural Settlements in China: A Systematic Review. *Land* **2022**, *11*, 1861. https://doi.org/10.3390/land11101861

Academic Editors: Guanghui Jiang, Yanbo Qu, Wenqiu Ma and Qinglei Zhao

Received: 29 September 2022
Accepted: 15 October 2022
Published: 20 October 2022

1. Introduction

In China, rural settlements play a pivotal role in the entire society. According to the report by World Bank, the rural land area in China in 2020 is approximately 5.3 million square kilometers (56.1% of the total area in China), with a rural population of approximately 529.47 million (37% of the total population in China). Based on the abovementioned information, it can be revealed that the environmental situations and residential experience of rural settlements have significant influences on the environmental quality and the residents' comfort all over China. Furthermore, the Chinese government determined the achievement of comprehensive rural revitalization as the Chinese national policy in 2021 [1]. Due to the proposal of the revitalization policy, the environmental quality and residential comfort of rural settlements in China have been attached significant importance by people from trades and professions in China [2–4].

Given the importance of rural settlements, it has become a community-wide consensus to improve the environmental quality and residential comfort of rural settlements in China [5–10]. However, compared to urban areas, the residential experience in rural settlements in China is still relatively backward due to the uneven development between urban and rural areas in China [11–13]. Moreover, due to the over-exploitation of resources and insufficient environmental awareness, the ecologies and environment of numerous rural settlements in China have been severely damaged [14–17]. From 2011 to 2021, China's rural resident population has declined by a cumulative 154 million people (19.05% of the total population in China), with an average of 15.4 million people per year [18,19]. According to the questionnaire survey by Song [20], only 14.3% of respondents preferred to live in rural settlements in China instead of urban areas. A critical factor that causes insufficient environmental quality and unsatisfactory residential experience is the inappropriate design and planning of rural settlements in China [17,21–25].

As a multi-function method, building information modeling (BIM) can provide significant contributions to the design and planning of rural settlements in China. BIM is a digital representation model based on the relevant information and data of the projects [26,27]. Through BIM utilization, it can provide 3d visual models, project simulations, collaboration platforms, and data storage and share for all stakeholders in the lifecycle of urban green infrastructure [28,29]. By adopting BIM in their design and layout planning, the stakeholders can effectively improve rural settlements' environmental quality and sustainability, enhance residential comfort, and reduce their costs and clashes [30,31]. According to the questionnaire survey by Huang et al., [30], 87.8% (180/205) of architects believe that BIM applications can facilitate integrated design, 86.34% (177/205) of participants insisted that BIM could facilitate efficient collaboration between stakeholders from multiple organizations, and 84.4% (173/205) of respondents acknowledged that BIM can effectively improve the quality of design and planning. Moreover, over 87% of respondents confirmed that BIM has significant contributions to improving projects' sustainability, optimizing the ecological environment, reducing energy and pollution emissions in buildings, and eliminating material waste [30]. In the case study of Ding et al. [32], BIM assisted designers in decreasing design changes by 30% and reworking by 25%. The questionnaire from Blay et al. [33] also demonstrates that 86% of respondents agree with the contribution of BIM in the request for Information mitigation, unnecessary change reduction, alternation duration optimization, and quality guarantee in the design process. Moreover, 68% of participants acknowledge that BIM can be effective in achieving cost conservation [33].

Despite the significant advantages of BIM utilization, many stakeholders are still reluctant to adopt BIM in the design and planning of rural settlements in China. A substantial barrier to BIM utilization is stakeholders' lack of familiarity with BIM's capabilities in the design and planning of rural settlements. Zuhairi, Abd. Hamid et al. [34] pointed out that the lack of knowledge of BIM is the most significant obstacle to BIM utilization. Olawumi and Chan [35] also developed that adequate familiarity with the BIM utilization method is essential in promoting BIM in the design and planning of rural settlements. Given the insufficient knowledge and understanding of BIM's contributions to the design and planning of rural settlements in China, designers and clients are hesitant to adopte BIM and pay extra expenditures for BIM applications [28,30,36]. According to the questionnaire surveys of Akhmetzhanova et al. [37] and Tatygulov et al. [38], 44% of respondents are reluctant to adopt BIM due to their unfamiliarity with BIM functions and insufficient appropriate BIM training. Furthermore, through the study of Huang et al. [30], it can be revealed that only 22.93% of respondents had participated in BIM training-related courses. It indicates that insufficient knowledge and familiarity with BIM capabilities is still a severe challenge in BIM utilization in the design and planning of rural settlements in China.

To enhance the BIM-related knowledge of rural settlements' designers and to promote the development of BIM utilization in the design and planning of rural settlements in China, this study is developed to conduct a systematic review to retrieve, summarize and discuss the contemporary BIM capabilities that can be utilized in the design and planning of rural settlements in China. According to the authors' search in WoS and Scopus in October 2022, there is no systematic review of articles focusing on the BIM capabilities in the design and planning phase of rural settlements in China. Although some excellent scholars perform remarkable reviews of the BIM utilization in the design phase [29,39–42], these studies are not specific to the BIM utilization in rural settlements' design and planning in China. Compared to conventional urban buildings, rural settlements in China have multiple unique characteristics that require the appropriate BIM capabilities to be adopted in their design and planning phase: Many rural settlements in China are located on mountains, valleys, plateaus, or nearby rivers, so it is necessary to be considered their surrounding environment, local ecology and the natural hazards' influence in their design and planning phase; The transportation system and road network in enormous rural settlements in China are common relatively backward; The small scale of budgets for their design and construction phase; Most buildings in rural settlements are houses rather than apartments and high-rise buildings. Therefore, it is necessary to provide specialized thermal analysis approach, daylight and wind environmental simulation method, and design and planning framework to the rural settlements in China. Besides that, despite some extraordinary articles having explored the BIM capabilities in rural settlements in China [43–47], these articles only explore partial BIM capabilities in the rural settlements in China rather than performing a comprehensive systematic review specific to BIM capabilities in the design and planning phase of rural settlements in China. Compared to the conventional article, the systematic review can provide a macroscopical perspective to gain comprehensive and integrated familiarity with BIM capabilities in rural settlements in China. Besides that, the systematic review method can support researchers in integrating available information and provide necessary knowledge support for decision-making through validated approaches [48–50]. Moreover, the compulsory studies retrieval and discussion procedures stipulated in systematic literature reviews can facilitate researchers to mitigate bias and optimize the reliability of research results [50–56]. In addition, given the rapid iteration and update rate of BIM, it is necessary to conduct a timely systematic review to review the latest BIM capabilities in the rural settlements' design and planning phase in China with the background of updating and alteration to BIM capabilities every year.

To fill the abovementioned research gaps, this study aims to perform a systematic review of the BIM capabilities in the design and planning phase of rural settlements in China. To achieve this aim, the following research questions are developed in this study:

1. What BIM capabilities can be adopted in the design and planning of rural settlements?
2. How are these BIM capabilities utilized in the design and planning phase of rural settlements in China?
3. What are the benefits, challenges, and future directions of BIM utilization in the design and planning of rural settlements in China?

To solve these research questions, the corresponding research objectives are developed in this study:

1. Identify the BIM capabilities that can be utilized in the design and planning phase of rural settlements.
2. Discuss and analyze the methods that BIM capabilities are performed in the design and planning phase of rural settlements in China.
3. Summarize the benefits, challenges, and future directions of BIM utilization in the design and planning of rural settlements in China.

This study can effectively enhance the knowledge of stakeholders on the BIM capabilities in the design and planning phase of rural settlements. Through this systematic review, BIM utilization in the design and planning process of rural settlements can be effectively promoted and optimized. Based on the research results in this study, the ecology, environment, and the inhabitants' comfort of rural settlements in China can be effectively enhanced.

The structure of this study is presented below: Section 1 is the introduction. In Section 2, the methodology is demonstrated. Section 3 contains the research results of this study. Furthermore, Section 4 demonstrates the discussion and analysis of the research results developed in Section 3. In Section 4, the advantages, challenges, and future directions of BIM utilization in the design and planning of rural settlements in China are summarized. Moreover, Section 5 is the conclusion. The detailed content of each section in this study is presented in Figure 1.

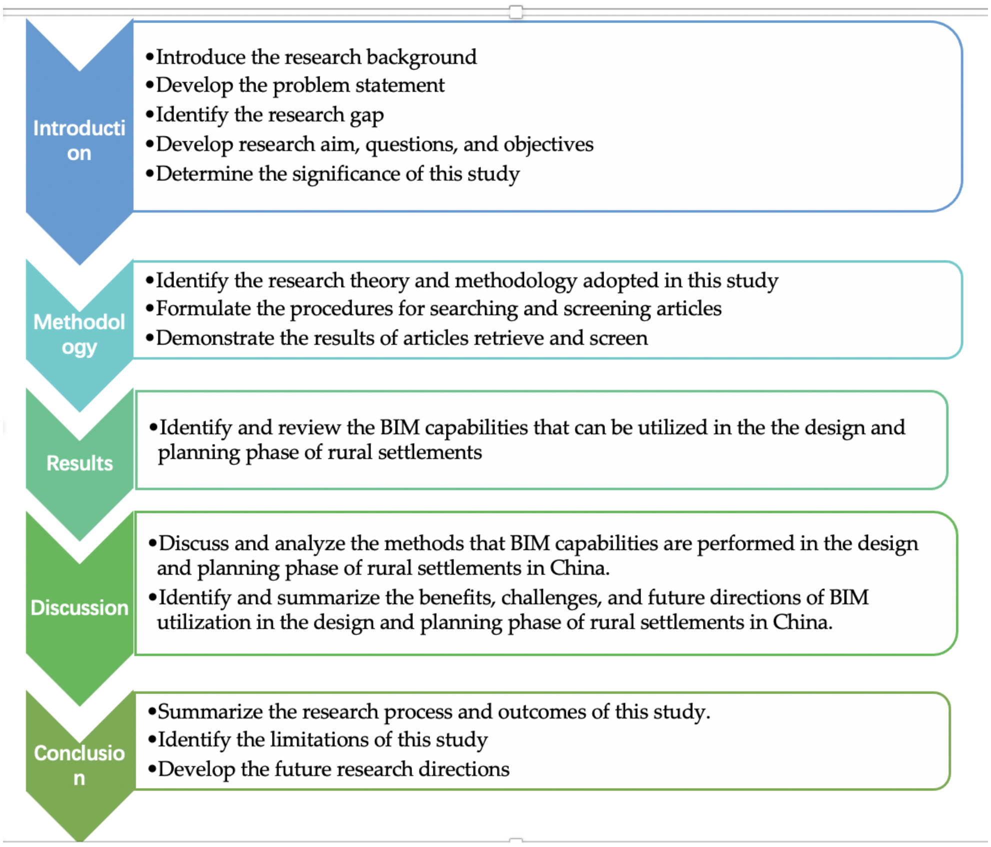

Figure 1. The detailed content of each section in this study.

2. Methodology

The systematic review has a fixed article search and screen procedure. In this study, the preferred reporting items for systematic reviews and meta-analyses (PRISMA) model are adopted to perform the systematic literature review of this study. PRISMA is a model for systematic literature reviews designed to support systematic reviewers in accurately identifying the data sources for the study, the criteria for screening and inclusion of articles, and the specific screening process [57–59].

In this study, the Web of Science (WoS) and Scopus are adopted as digital data repositories, which were also adopted as the data source in multiple systematic review studies [51,60–66]. Based on the abovementioned research aim and objectives, the following meanings are determined to conduct the article search in this study: "BIM", "Building Information Modeling", "artificial intelligence", "digital twin", "rural settlement", "rural land", "rural layout", "design", "plan". Then, the inclusion and exclusion criteria are determined, such as in other systematic review studies [56,62,67–69]. To perform the systematic review effectively in this study, the following inclusion criteria are developed by the authors (The detailed inclusion criteria and exclusion criteria are presented in Table 1):

1. The journal articles, reviews, and conference papers can be searched through WoS and Scopus.
2. The journal articles, reviews, and conference papers are written in English and can be retrieved in full text online.
3. The journal articles, reviews, and conference papers that include the BIM capabilities in the design and planning of rural settlements.
4. The journal articles, reviews, and conference papers contributed to solving this study's research aim and objectives.

Table 1. Inclusion criteria and exclusion criteria.

Primary Criteria		Secondary Criteria	
Inclusionary	**Exclusionary**	**Inclusionary**	**Exclusionary**
Journal articles, reviews, and conference papers can be searched in the databases of WoS or Scopus.	Duplicated papers	The articles that can support authors to accomplish research aim or objectives.	The articles cannot provide support for authors to accomplish research aim and objectives.
	Invalid articles (the articles that cannot provide the online version of full-text content.)		
Written in English	Written in Non-English.		

Furthermore, the exclusion criteria in the process of article search and screening are demonstrated as follows:

1. The journal articles, reviews, and conference papers are written in non-English or cannot be retrieved in full text online.
2. The duplicated articles were retrieved in both WoS and Scopus.
3. The journal articles, reviews, and conference papers that do not include the BIM capabilities in the design and planning of rural settlements.
4. The journal articles, reviews, and conference papers are not contributed to solving this study's research aim and objectives.

The search string and initial search results are presented in Table 2. After the article search, 1226 articles are retrieved from databases (718 in WoS, 497 in Scopus). After removing the duplicated and invalid articles (those without full text online), 1013 articles remained. Then the remaining articles are delivered to the next step to perform titles, keywords, and abstract screens. There are 462 articles removed in this step. Then, the remaining 317 articles performed the qualitative assessment by reviewing their full text. Finally, 189 articles are contained in this study. The process of article retrieval and review is shown in Figure 2.

Table 2. Search strings and screen process.

Search Engine	Search String	Results
WoS	TS = ((“BIM” OR “Building Information Modeling” OR “artificial intelligence” OR “digital twin”) AND (rural) AND (design OR plan OR layout OR development OR revitalization))	729
	Document Types: Articles or Proceedings Papers or Review Articles	725
	AND LANGUAGES: (ENGLISH)	718
Scopus	TITLE-ABS-KEY ((“BIM” OR “Building Information Modeling” OR “artificial intelligence” OR “digital twin”) AND (rural) AND (design OR plan OR layout OR development OR revitalization))	616
	AND (LIMIT-TO (DOCTYPE, “ar”) OR LIMIT-TO (DOCTYPE, “cp”) OR LIMIT-TO (DOCTYPE, “re”	521
	AND (LIMIT-TO (LANGUAGE, “English”))	508
Total		1226

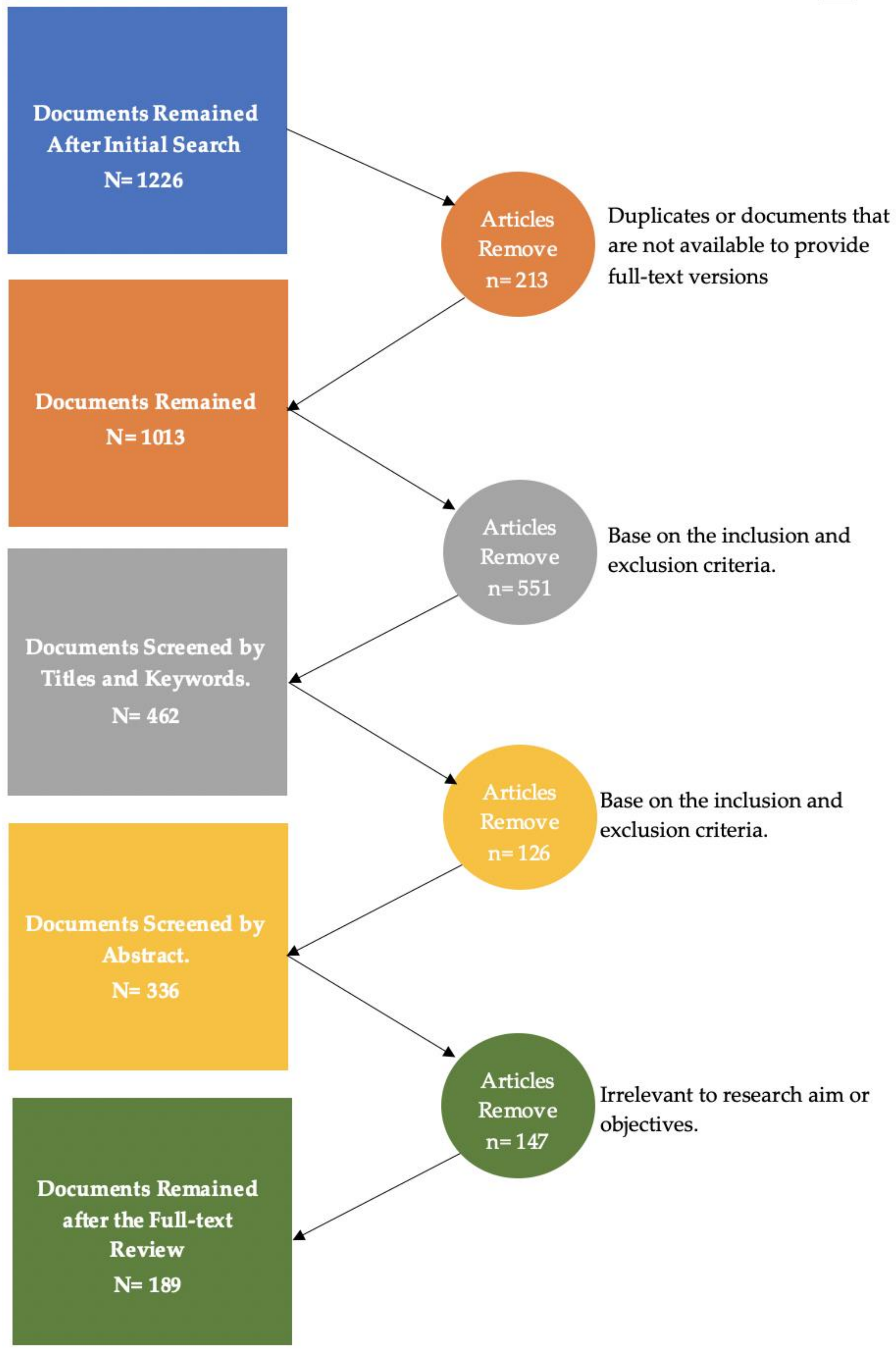

Figure 2. The flow chart of article searching and screening.

3. Research Results

After the article search and screening process was completed, the remained articles were performed in the systematic literature review. The results of the systematic review are presented in Section 3.

3.1. Descriptive Analysis

Through the article retrieval and screening, it can be determined that 189 articles are contained in this systematic literature review. Figure 3 presents the number of articles published per year. From 2007 to 2022, the number of articles on BIM capabilities in the design and planning of rural settlements demonstrated a significant upward trend. From 2007 to 2013, the research in this direction is in the initial stages. From 2014 to 2016, the BIM capabilities in the design and planning of rural settlements received extensive attention from the AEC industry, and the number of articles on this direction dramatically increased. Since 2017, research in this field has been flourishing. According to Figure 3, it can be concluded that the research on BIM utilization in rural settlements' design and planning phase has been attached importance by tremendous scholars. During this period, not only has the number of articles on this field been steadily increasing each year, but the number of papers reviewed each year is more than 20. In 2022, The number of selected articles that were published in 2022 even reached 33.

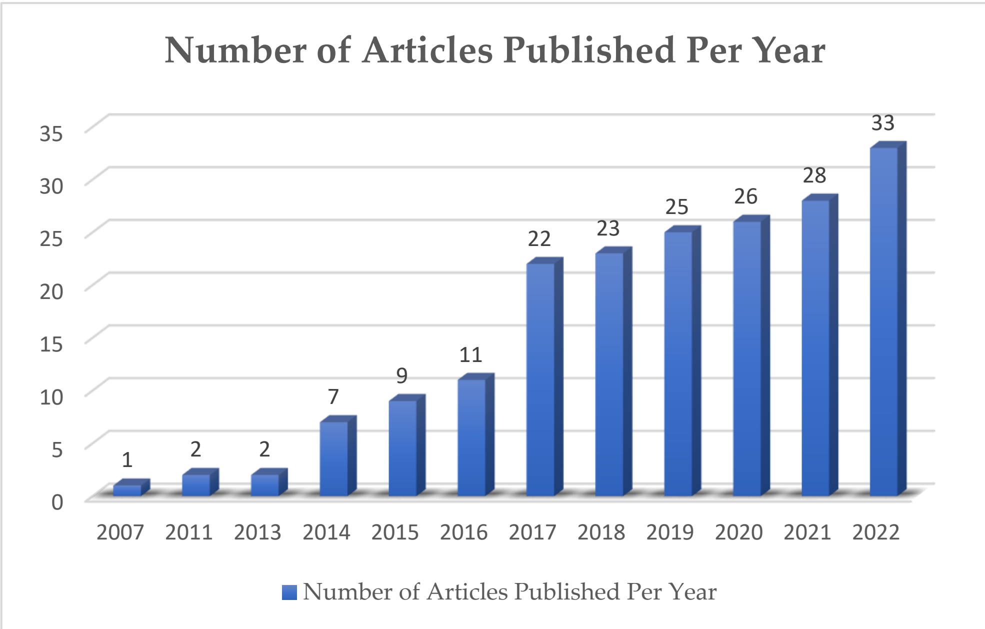

Figure 3. The number of selected articles published per year.

According to Figure 4, it can be summarized that these 189 reviewed articles are retrieved from 86 journals and 8 conferences. Based on the number of articles that originated, the authors developed the rank of the journals and conferences in Figure 4. The rank of journals and articles is presented below (Only the top 10 journals are listed because of the lengthy limitation in this study): Automation in Construction (25), Buildings (9), Land (7), Sustainability (7), Procedia Engineering (6), Advanced Engineering Informatics (5), Applied Sciences (4), Journal of Computing in Civil Engineering (4), Renewable and Sustainable Energy Reviews (4), Building and Environment (4).

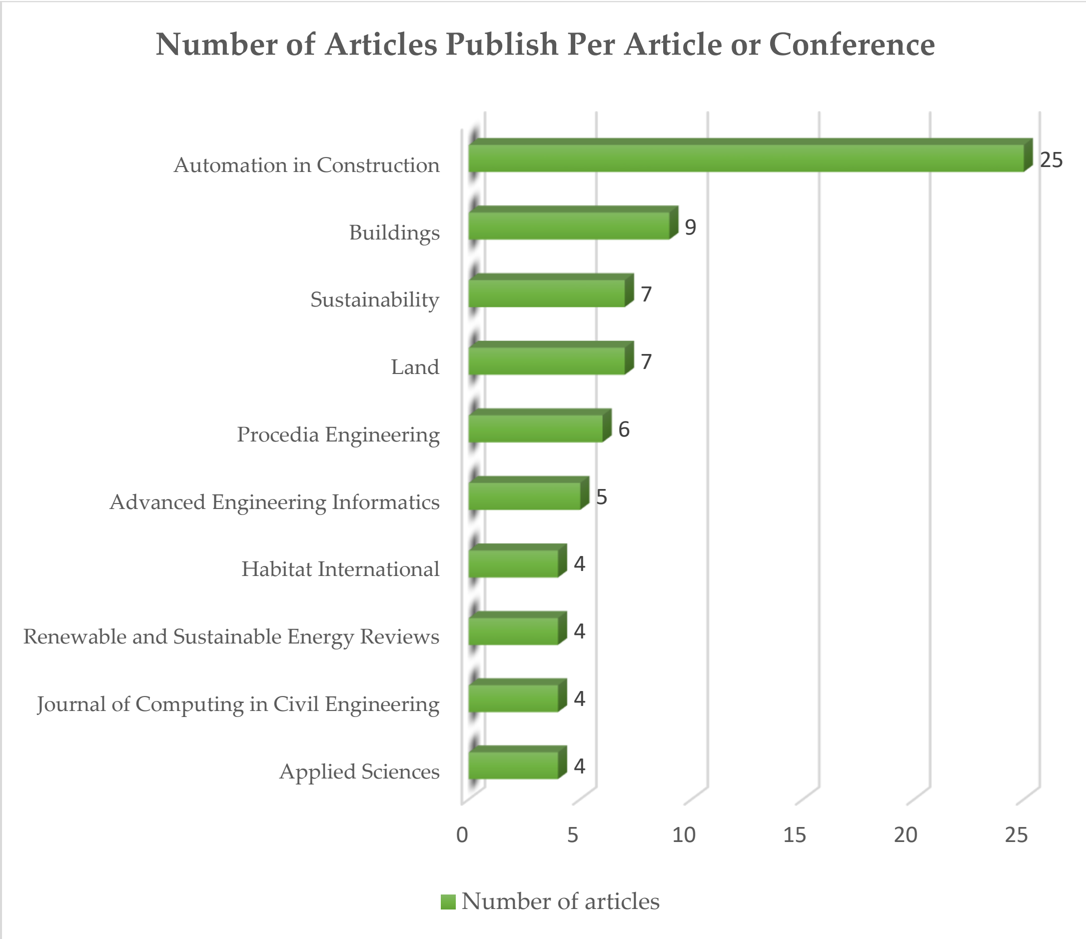

Figure 4. The number of reviewed articles included in the journals or conferences.

3.2. Results Analysis

Through the systematic review of these included articles, the BIM capabilities that can be utilized in the design and planning of rural settlements are identified and summarized. According to the characteristics of these identified BIM functions, the BIM capabilities that can be utilized in the design and planning of rural settlements can be categorized as the following perspectives: Data storage and management; 3D modeling and visualization; Disaster prevention and environmental analysis; Cost estimation and optimization.

3.2.1. Data Storage and Management

The BIM capabilities for data storage and management can be utilized throughout rural settlements' entire design and planning phase. By importing information about urban planning and the surrounding environment into BIM, BIM can prepare the necessary knowledge about rural settlement layout and the surrounding environment before the design and planning process begins. There are three approaches for BIM utilization to capture knowledge and experience in the design and planning process of rural settlements: Utilize customized parameters in the BIM model to search for knowledge; Utilize application programming interfaces (APIs) to implement parameters in the BIM approaches through third-party software or web-based systems; Adopt the external knowledge retrieval devices to capture knowledge [70–73].

In the early design preparation phase, the BIM database allows individual stakeholders to input their demands into the BIM database through text and image format [74,75]. It can facilitate the designer to review the requirements in rural settlements' entire design and planning process [74–77]. Moreover, given that all data and knowledge files in BIM are in the uniform format (IFC or gbXML), it is convenient for stakeholders to import, retrieve and browse the required data and knowledge throughout the entire design and planning process of rural settlements [78–83]. Moreover, the LoD (Level of Detail/Development/Definition) is also an essential characteristic of BIM in the design and planning process of rural settlements. The LoD can categorize and manage data and knowledge according to their level, and provide the corresponding information to the rural settlements' stakeholders according to their required information level [84–86]. For example, in the case study of H. Liu et al. [87], the information and knowledge are classified to LoD 100 (the basic requirements of the BIM model, including the volumetric information about the target objectives, including its dimensions and materials,); LoD 200 (the information related to the frame safety performance evaluation); and LoD 300 (the knowledge related to high-fidelity representation).

The collaboration among stakeholders in the rural settlements' design and planning phase can be significantly enhanced through the information storage and management function in BIM utilization. In BIM-based collaborative design and planning software, all individual stakeholders can make their own suggestions and requirements throughout the design process [88,89]. The characteristics and benefits of BIM-based collaborative platforms can be summarized in the following aspects: The interior model databases linked up to other BIM central databases; Cloud-based data exchange and management system; The designations (global unique identifier) given to the elements, components, materials and structures in the models; The knowledge exchange procedure and regulations based on the information delivery manuals (IDM); Information categorization and knowledge security based on stakeholders' requirements [90,91]. By the characteristics mentioned above, the information exchange efficiency is increased, and information losses in the knowledge exchange process are mitigated. Furthermore, In the BIM cloud plugin developed by Kalasapudi et al. [92], any changes and additions made by stakeholders can be uploaded into the central database and promptly reflected in other stakeholders' interfaces. It can facilitate the stakeholders to grasp the latest project conditions in rural settlements' design and planning phase [61,92].

Moreover, with the integration of BIM and third-party devices, the rural settlements' layout information and surrounding environment conditions (such as topography, terrain, climate, hydrology, soil, and vegetation) can be automatically retrieved and stored into BIM for further analysis [51,93–96]. By association with BIM and weather stations, C.-J. Chen et al. [97] developed virtual weather station technology adopting BIM cloud tools to support rural settlements stakeholders to retrieve and manage the information about local climate automatically, and the retrieved knowledge can also be transferred to the DOE-2 engine based on IFC (Industry foundation class) format to support subsequent environmental simulation for rural settlements. In the knowledge management model developed by Wang and Leite [72,73], the data and knowledge produced in the mechanical and electrical layout planning collaboration meetings can be categorized and integrated into BIM through the application programming interface (API) and other plug-ins.

From the perspective of environmental information management, BIM and GIS can be complementary [98]. BIM places emphasis on the design process and the management and modeling of information at the building and structure level, while GIS is adept at the management and presentation of environmental information at the overall regional level [99–101]. With the integration of BIM and GIS (Geographic information system), the rural settlements designer can effectively review the local environmental information with multiple levels of detail to optimize their planning [94,102–105]. Based on the same data exchange formats (City Geography Markup Language and Industry Foundation Class), the information compatibility and interoperability between BIM and GIS can be effectively implemented, which ensures the effectiveness and accuracy of the rural settlements' conditions and surrounding environment situations presented in BIM [94,98,102,104,106–108]. In the case study of Pepe et al. [109] and Tsilimantou et al. [110], the researchers utilize the UAV (unmanned aerial vehicle) to perform ground-based laser scanner technology and close-range photogrammetry to generate data relating to the external geometry of multiple buildings and structures in the selected area. After the abovementioned information collection and process is completed, these data can be displayed through BIM and GIS as the human-computer interaction interface. In addition, through the implementation of infrared thermography, ground penetrating radar, and ultrasound, Tsilimantou et al. [110] collected the materials characteristic of existing buildings in the local area through BIM-GIS integration to simulate the aging state and service life of each building. Furthermore, for the Urban Information Modeling (UIM) developed by Mignard and Nicolle [111], it can be utilized to conduct the management of information and knowledge utilizing semantic BIM for each geographical factor, building element, and component characteristic in specific areas. Based on these capabilities, stakeholders can use the BIM-GIS-based UIM to access the status of buildings or components at different phases in their lifecycle and estimate their expiration dates [111].

Moreover, by integrating BIM and the Internet of Things, BIM can effectively record and report real-time conditions and alter rural settlements' layouts [94,112,113]. In the process of BIM-IoT integration, IoT enables the transfer and integration without omission of data collected through sensor pairs and knowledge retrieved through the network via IoT protocols [114,115]. Based on the IoT gateway as an interaction intermediary for integrating multiple sources of retrieved data, the IoT can facilitate the classification and integration of data sets from multiple probes, which can effectively optimize the interoperability of BIM with third-party devices and software [116]. Once the data has been integrated and categorized, BIM can be utilized as the human-machine interface based on its powerful data management and visualization capabilities to provide stakeholders with visual information demonstration that enhanced by real-time sensing information [116]. Compared to the conventional environment monitor system, BIM-IoT integrated approach can not only implement the polychrome visual presentation of data from multiple individual sensors but also enable macro-level visualization of predicted mean vote (PMV) data for the entire rural settlement [117]. To enhance the data visualization performance of BIM-IoT integration in the design and planning phase of rural settlements in China, augmented reality (AR) is recommended as the auxiliary approach in the BIM-IoT implementation process. In the case study of Natephra and Motamedi [118], the researchers used AR technology to achieve a dynamic visual display of environmental comfort. This method can achieve the high-fidelity dynamic presentation of data related to air mobility, air quality, light radiation, thermal radiation, and hydrology of the environment in the selected rural settlements [118]. In addition, to enhance the semantic accuracy and user-friendliness of BIM-IoT integration, a browser/server framework-based optimization path for BIM information interaction procedures and document light-weighting is proposed by Yuan et al. [119]. This approach supports stakeholders in extracting semantic information and geometric data from IFC files in BIM, based on which the Draco algorithm and compression parameters can be performed to achieve the light-weighting process with a compression ratio of approximately 80% without information omission [119].

Customized information retrieval and management is also an essential advantage of BIM utilization in the design and planning of rural settlements [71,72,120,121]. In the BIM-based knowledge management model developed by H. Wang and Meng [121], the customized parameters can be utilized for the stakeholders to identify and capture the required knowledge of specific assets. From the perspective of knowledge search and retrieval, Deshpande et al. [70] and H. Wang and Meng [72] put forward that knowledge and information can be categorized according to their attributes (such as location, category, function, designer, component, and material) to facilitate the stakeholders to retrieve the specific category of information. Furthermore, Case-based reasoning (CBR) is also deemed a vital trend of BIM utilization in rural settlement projects' design and planning process and their corresponding solutions. The CBR-BIM-based model can record the problems in the design and planning process of rural settlement projects and their corresponding solutions [63,122–126]. In the issue resolution process, the model can automatically retrieve similar previously recorded and encountered situations through the BIM database and match the stakeholders with the corresponding solutions [124,127–130].

3.2.2. 3D Modeling and Visualization

In addition to the knowledge preparation, multi-dimensional visualization modeling can also be provided through BIM utilization. Compared to traditional 2D drawings, BIM can provide designers with visual 3D models of rural settlements and the surrounding environment, facilitating stakeholders to understand site conditions and optimize the design and planning schemes better [30,131–133]. In the BIM tool established based on high-fidelity point-cloud data developed by H. Liu et al. [87], BIM can enable both the presentation of the entire rural settlements' projects and the 3D visualization of specific buildings, floors, or components. Moreover, the parameters of each component can be presented to stakeholders through BIM 3D visualization. Compared to the conventional 3D visualization tools, there are some significant advantages in BIM: Concise data and light internal storage requirements; Applications can be utilized across multiple platforms; Open access to data and information [134]. In addition to these, BIM can increase the multi-dimensions" presentation efficiency through the adoption of the level of detail (LOD) and the invisible components' concealment compared to traditional visualization methods [135]. From the perspective of visualization in the rural settlements design and planning stage, LoD can decrease the level of detail of the project when stakeholders observe the lands from distant viewpoints to provide a comprehensive overview with optimized performance [136,137]. Furthermore, it can provide more detailed properties by increasing the level of detail of the components within the designer's field when viewed from close viewpoints [138]. Furthermore, through the invisible components' concealment, BIM can be settled to not render and load the invisible structures in the current view to augment the performance of 3D modeling and visualization of the demonstration [135].

With the integration of BIM 3D modeling and schedule management, BIM 4D can assist the stakeholders in becoming familiar with the project progress at different points in time and then optimize their design and planning schedules [139–141]. In the BIM-based approach developed by Ding et al. [142], the real-time rural settlements' environmental situation and layout alteration can be presented continuously in 4D BIM-based tools, and the corresponding quality supervision lists can be put forward for each step during the design and planning process. In the CasCADe application formulated by Ivson et al. [143], it can visualize the structures and changes of the project at different nodes according to the tasks' sequence in a temporal and spatial simultaneity manner. Moreover, BIM can demonstrate the ownership and boundaries of the plots, buildings, and infrastructure of the rural settlements as the 3d model presentation. In the BIM-based land administration domain model (LADM), BIM presents the cadastral data of the entire settlements and the legally defined boundaries of land parcels and assets through the 3D visualization pattern by embedding 3D cadastre into digital visualization models [105].

Through the combination of BIM with third-party equipment and plug-ins, the 3D modeling and visualization performance can be effectively optimized in the design phase of rural settlements. In the BIM-GIS-based model developed by Park and Kim [99,144], BIM can automatically retrieve the maps, satellite photos, land registry form, and land planning information for the target areas, thus automatically generating the 3D models to optimize the layout of rural settlements. Throughout the process of BIM-GIS integrated modeling, BIM environments built on the IFC as a standard base can translate their geometric and semantic information into shallow models that can be interpreted by GIS applications [145]. To enhance the integration maturity between BIM and GIS in the modeling process, Deng et al. [146] and Hor et al. [147] suggested that efficient integration of BIM-GIS can be achieved by configuring the Resource Description Framework (RDF) and developing IFC-CityGML interactive criteria. Moreover, BIM for Geo-analysis (BIM4GeoA) has been identified as the maturity improvement method to BIM-GIS integration by utilizing and integrating commonly acknowledged open-source applications and open specifications to perform structural building data and information management within the scope specified in the model [145,148]. Based on these optimization approaches, the stakeholders can extend the scope of modeling and visualization from architectural complexes to the entire rural settlements and their surrounding environment [145,149].

The efficiency of BIM-GIS integration in 3D modeling and visualization has been proved by multiple case studies. In the BIM-GIS-related studies of Dore et al. [150] and Pepe et al. [109], the researcher proposes the method for constructing BIM-GIS visualization models based on laser scanning and photogrammetry data. Through the utilization of close-range photogrammetry (CRP) techniques and ground-based laser scanning (TLS), this method can efficiently collect ground environment data to generate point or planning grids from which 3D models can be constructed. Besides that, Nappo et al. [151] developed Unmanned Aerial Vehicle (UAV) adopted information collection and modeling approach. This method utilizes the UAV and configured laser profiler or infrared thermal imaging detection tool to scan the local road network and infrastructure to create the ultra-resolution 3D point cloud model [151]. In the service-based virtual 3D city model system developed by Döllner & Hagedorn [152], BIM, CAD and GIS are seamlessly integrated into the single system for the stakeholders to access. The system allows designers to view and compare 3D stereo models, 2D plan information, and aerial views of specific areas to support their designs better [152]. From the perspective of feasibility analysis, the assessment approaches developed by Lotai and Trivedi [153] and Zhu and Wu [154] can import and present multiple layout schemes in BIM. By comparing the 3D modeling of the rural settlements in BIM with site blocks in the GIS map, the feasibility analysis of the proposed layout plans can be effectively achieved by this assessment approach [94,99,155–157].

Moreover, through the integration of IFC and WebGL, WebBIM can mitigate the amount of redundancy required for 3D modeling in BIM by sharing geometric data among the objects that are produced from identical origins to assist other stakeholders in rendering and presenting visual multidimensional modeling of corresponding rural settlements directly through browsers without BIM software [134]. In addition to these, the combination of BIM with VR (Virtual reality) and AR (Augmented reality) has also become a trend in the rural settlements' design process [158]. The integration of BIM with VR and AR not only enhances the level of detail and operability of the BIM visualization but also optimizes the user's immersion and supports stakeholders to be familiarized in detail with the environment and building plans of targeted rural settlements through the first-person perspective [159–161].

3.2.3. Disaster Prevention and Environmental Analysis

- Disaster Prevention

Disaster is the general term for incidents and phenomena that can devastate human existence, such as hurricanes, earthquakes, tsunamis, mudslides, and floods [162–166]. Given that tremendous rural settlements in China are near rivers, valleys, mountains, cliffs, and seas, disaster prevention is essential to rural settlements in China [167–170].

Through the BIM-GIS model, the rural interior plan and the village surroundings (climate, topography, terrain, and hydrology) can be presented in 3D modeling, which can provide necessary information to stakeholders for disaster identification and prevention. From the perspective of earthquake prevention, Anil et al. [171] developed a BIM-based earthquake damage prediction method. By incorporating information on building structure and geometry, materials and equipment utilization conditions, refurbishment records, surrounding terrain, and hydrology into the BIM evaluation framework, Anil et al. [171] utilized the FEMA 306 guidelines to predict the resilience of different design and planning schemes to different intensities' earthquakes. In the case study of Welch et al. [172], the researchers evaluate the seismic capabilities of the complex assets through the BIM simulation function by inputting their structure and materials into the BIM model. To optimize earthquake prevention measures in the design and planning phase of rural settlements, Vitiello et al. [173] utilized the simulation capabilities and LoD in BIM to estimate the intervention's effect of various disaster prevention measures to optimize the distribution of non-structural architectural elements. In addition to these, in the seismic optimization approaches of sprinkler systems put forward by Perrone and Filiatrault [174], the non-structural elements' seismic framework was effectively improved through the information capture and scenario simulation capabilities of BIM.

From the aspect of mudslides prevention, Chang et al. [175] proposed the BIM-based landslide monitoring and prevention model by integrating CATIA (computer-aided three-dimensional interactive application) application. Through this mudslide prevention method, the dynamically coordinated landslide simulation model can be generated by collecting and analyzing the mountains' 3D spatial point sets and topological relationships to predict the probability of landslide occurrence and the damage caused by the rural settlements [175]. Furthermore, cyber-physical systems (CPS) can also provide significant contributions to BIM-based disaster prevention. With the integration of BIM and CPS, the stakeholders can effectively utilize the accurate remote sensing and intelligent supervision technology for multi-source knowledge, the reliable information transmission frameworks for the communication interior framework, and the algorithms for instant identification of the structure in the BIM knowledge repository in BIM [176–179]. Based on the above technology, BIM can automatically collect environmental information about the target area via remote sensors and the information records on disasters that occur through the internet to conduct an environmental simulation to identify potential disaster risks in the corresponding area [177].

For those rural settlements located along the river, BIM utilization in the design and planning stage of rural settlements is essential in mitigating flood damage [145]. In the flood-preventative renovation design and planning process of rural settlements and urban in Guangzhou, Lyu et al. [180] modeled the topography of the entire area in the 3D visualization approach by implementing the BIM-GIS integrated Digital Elevation Model (DEM). By importing the precipitation information, the drainage pipes' distributions, and the drainage capacity of traffic pavements in each area into the DEM, the designers analyzed the extent of damage caused to the rural settlements and the city by flooding during the rainy season in the area, to develop the corresponding renovation planning scheme [145,180]. Since most Flood damage assessment (FDA) methods lack the incorporation of individual building characteristics in rural, Amirebrahimi et al. [181] propose an integrated BIM and City GML approach to Flood damage evaluation. By referring to the detailed geometric information, structures, and materials of the individual assets within the rural settlements to simulate the damage level to individual buildings during a flood and implement targeted optimization initiatives during the design and planning phase of the rural settlements [145,181,182]. In addition to these, in the design and planning process of evacuation and escape routes in rural settlements, BIM can integrate information on disaster prevention equipment, local environment, transportation conditions, and regular residents' activity patterns into a model to simulate the most appropriate evacuation and escape routes [183–186].

- Environment Analysis

Through the utilization of BIM in the design and planning phase of rural settlements, the stakeholders can effectively perform daylight and illumination simulation, wind environment simulation, and thermal environment simulation. Based on the mentioned simulations, designers can modify their plans during the design and planning process of the rural settlements. These capabilities can improve the rural settlements' natural environment and residential comfort, reducing their energy consumption.

In the process of wind environment simulation, the BIM capabilities can provide significant contributions to wind tunnel aerodynamic analysis and computational fluid dynamics (CFD). In the wind tunnel aerodynamic analysis, The BIM can integrate the monitoring data for wind pressure from the various wind pressure measurement detections and data monitoring probes [187–189]. The wind-related statistics can be performed analysis, simulation, and visual presentation by utilizing the Wind Engineering Data Analysis tool (WEDA) [188]. Through these measures, the stakeholders can simulate the wind pressure and loads that different layout schemes of rural settlements can withstand, thus providing knowledge support for layout optimization [190,191]. From the aspect of BIM utilization in CFD, BIM can generate and analyze the wind direction and wind levels for each season of the rural settlement through the integration of BIM, pressure monitoring points (probes) with computational wind engineering (CWE) approaches [192,193]. Based on the stored building layout, wind information, and the required different level of development (LOD), BIM can develop the 3D STL ("Stereolithography") wind models to simulate and demonstrate the wind flow paths in different design and planning schemes of rural settlements [188]. Based on the above-mentioned BIM capabilities, stakeholders can effectively conduct the design and planning schemes' optimization. For example, in the case study of Xu et al. [194], the researchers utilize the BIM-based CFD simulation software to draw two conclusions that contribute to the optimization of wind environment design: When an appurtenance exists on the external wall between two adjacent buildings, their "Venturi effect" between them will be decreased; The block walls with the massive area can enhance the vortex area on the surface of the structure.

After the wind simulation is completed, the simulation results can be presented in both the CFD visualization method and the 3ds max visualization method [195]. These demonstration methods can present wind routes in the simulation space as particle tracing lines and support virtual reality (VR) simulations [195]. In the BIM-VR integrated wind simulation tool developed by Çöltekin et al. [196] and Hosokawa et al. [197], BIM can generate immersive CFD models based on the design and layout of rural settlements, thus enabling designers to understand the wind flow in detail for each design schemes.

In addition to these, the simulation capabilities of BIM can also provide significant advantages for thermal environmental analysis in the rural settlements' design and planning process. The BIM-based thermal simulation and analysis usually contain the following steps: establish the 3D visually BIM model of rural settlements; retrieve thermal-related environmental information; input the collected information into the BIM model point by point; identify thermal comfort variables; assess the thermal comfort of selected rural settlements [198–200]. In the thermal comfort assessment method formulated by Natephra et al. [199], the BIM-based thermal comfort analysis framework utilizes the environmental probes to collect the temperature, humidity, and daylight localities to collect and integrate the thermal-related information. After the data preparation is completed, the stakeholders can utilize the predicted mean vote (PMV) method, the predicted percentage of dissatisfaction (PPD) method, and the adaptive method model method to perform a quantitative analysis of the thermal comfort in the selected rural settlements [199]. In the ModelicaBIM library, BIM can record and collate the temperature, sunlight situation, buildings' layout, and thermal conductivity of periphery materials in particular rural settlements each month, so that the indoor and outdoor temperatures of the structures in the selected area and their heat loss in winter can be simulated precisely during their design phase [201].

Moreover, according to the different requirements of stakeholders, the BIM-based thermal comfort can perform targeted thermal simulations at building and component levels to evaluate their heat transfer efficiency in different seasons [201]. Furthermore, to simulate the thermal environment during the design and planning phase of rural settlements during their life cycle, Ham and Golparvar-Fard [79] incorporated the factor of building materials' aging into their proposed thermal comfort analyzing framework. By simulating the decay of the thermal resistance of different building materials over time, the users can optimize the indoor thermal environment's simulation method and analysis algorithm [79]. In addition, given that winter temperatures in the Northern regions, Northwest region, and Qinghai-Tibet of China are generally below 0 degrees Celsius, the winter heating in the rural settlements in these regions consumes massive energy and cost. To solve this barrier, The Revit—Dynamo integrated BIM-based thermal analysis framework can identify the insulated structure's performance and its envelope's thermal conductivity by analyzing envelopes' insulation attributes [202–204]. To optimize the assessment of the facades' thermal conductivity, Iddon and Firth [205] and Gbadamosi et al. [206] proposed to utilize BIM material database to assess the thermal conductivity and insulation of facades in different environments by importing the type and thickness of the insulation materials to be adopted. And Jalaei and Jrade [202,207] indicated that it is available to deduce the thermal conductivity and resistance of building insulation by outsourcing to third-party software through the interactive transfer of the BIM model data in gbXML format to the Ecotect or EnergyPlus energy simulation application. In the case study of Chen et al. [202], through the utilization of the Dynamo building materials analysis application incorporating the NSGA-II algorithm, the researcher developed separate analytical objective functions which are aimed at evaluating the embedded energy of specific insulated areas and the thermal energy demand of external wall surface to optimize the thermal insulation properties evaluation. In addition, based on the various regional climates of China, Ounis et al. [203] adopted the EnergyPlus engine to derive the thermal transmittance (U-Value) for each envelope material. Based on the abovementioned characteristics, the BIM-based energy simulation approach can assist the stakeholders in identifying the most appropriate U-value for different climatic zones and achieving a dynamic balance between thermal insulation and heat dissipation in buildings [203]. To balance the overall thermal transfer value (OTTV) metric and construction costs, the thermal environment modeling approach developed by Seghier et al. [204] to perform data interaction through visual script and generate thermal performance optimization solutions through applicable case analysis in the MATLAB protocol. Based on the results of this analysis, the designers can effectively optimize their rural settlements' design and planning schemes to achieve the dynamic balance between the energy consumption of the insulated frame and the thermal performance of the envelope [202].

From the perspective of daylight environment simulation, BIM can effectively simulate the light conditions of indoor and outdoor environments and their changing patterns at different times in different seasons. Based on the above information, designers can effectively optimize building layouts and design solutions for rural settlements to improve the indoor light environment, thereby reducing energy consumption and enhancing the occupants' comfort. According to the review of Iversen et al. [208] and Jakica [209], BIM-based daylight environment simulation can be performed mainly through the following modes: Split flux formula (Importing the area of the open area, internal and external reflective properties into the formula to calculate daylight conditions); Finite element methods (The interaction mechanism between light is modeled through the utilization of linear system equations, and then the stakeholders can simulate daylight condition through global rendering equations); Monte Carlo based methods (Recursive tracing of light transmission paths based on the principle of Multiple Importance Sampling); Hybrid mode (Optimize the simulation of specular light reflections in the environment based on the combination of ray tracing and rasterization). In the Monte Carlo method adopted daylight simulation case conducted by Schregle et al. [210], the researcher utilizes the photon mapping method to simulate the effect of diffuse reflection of internal structures on the light environment. Then, the daylight environment of the structure was simulated by forward and backward ray path tracing [210].

In addition to these, through the BIM-Energy Plus integrated framework, the stakeholders can simulate the sunshine duration and the uncomfortable daylight duration of occupants in different rooms in the multiple rural settlements' design and layout schemes based on the buildings' envelopes, location, and psychology [211,212]. In the uncomfortable daylight duration estimation process, BIM can retrieve and manage the sunrise and sunset times points, sunlight intensity and direction, and solar radiation angle for the area each month to assist the daylight environment analysis [132,212]. After uncomfortable daylight hours are identified, the multi-objective optimization schemes of rural settlements' design and planning can be developed based on the genetic algorithm [212,213].

3.2.4. Cost Estimation and Optimization

In the rural settlements' design and planning phase, the contributions of BIM in cost analysis and optimization can be presented in the following aspect: Preparation of bill of quantity, budget estimation, and expenditure optimization.

- Preparation of Bill of quantity

During the entire design, upstream clients and downstream contractors can use BIM to provide immediate feedback and alter based on their budget requirements. This facilitates the designer to alter the design schemes in time to meet the cost requirements of the client and contractor. Moreover, given that all the elements (such as walls, windows, columns, and beams.) and structures developed in the process of rural settlements design can be recorded through IFC format into the BIM data repository, the bill of quantity can be automatically generated in the design phase [214]. In the BIM model that LoD 300 can be implemented, it can provide the following detailed information about the target structure: geometry (length, breadth, height, volume, and superficial area); the quantity of materials and equipment required to establish the structure; relationship to the entire rural settlement; varieties and attributes of materials; relationship to the other elements in contact with it [214–216].

Based on the abovementioned functions, designers can efficiently and accurately count the materials and devices consumed in the corresponding design and layout planning scheme. The BIM-based quantity takeoff code mapping (BQTCM) method has been proposed by B. Chen et al. [217] to generate bills of quantities more efficiently. Through the BQTCM plug-in, the items in the bill of quantities that are produced in conventional patterns can be converted into objects in IFC format without information omission during the interaction, thus generating the bill of quantities of assets, structures, metallic materials, and concretes in the design and planning phase of rural settlements [217]. Furthermore, compared to the regular manually formulated bill of quantities compilation mode, BIM can automatically update its bill of quantities as the modifications are made to the design scheme, thus avoiding tediously repetitive work [218,219]. In the case study of Zima [214], the researchers can utilize BIM to estimate the required person-days and human resources of different occupations from the bill of quantities generated during the design and planning stages, thus calculating the human resources expenditure required for the project. Multiple studies were developed to improve the accuracy of the BIM-generated bill of quantities. Khosakitchalert et al. [220] optimize their capture approach of incomplete or inaccurate composite elements by integrating the principles of BIM clash detection into the estimation process for materials and equipment. In the BIM utilized accuracy method of the bill of quantity takeoff method (BCEQTI) developed by Khosakitchalert et al. [220], BIM can identify components that have been duplicated during the bill of quantities generation and remove them out through the clash detection capabilities and avoid duplicate counts of components by modeling each material layer independently. Based on these contributions, the method also reduces the workload and duration during the model alteration process. Moreover, in the BIM-based automatic compound element modification (ACEM) method of composite components and structures that were put forward by Khosakitchalert et al. [221], the overlaps in the BIM model can be identified and excluded by dissociating the composite elements into individual model elements and conducting the reciprocal comparisons among individual structures and elements. According to Khosakitchalert et al. [221], the procedure of ACEM utilization contains 5 steps: Retrieval of the data required for quantity calculations in BIM; Extraction and classification of the core structural layers of the wall panels and floors in the building; Reconstruction of the facades based on the information management and modeling capabilities of BIM; Reconstruction of the internal load-bearing walls, shear walls, and floors based on the data collected in step one; Execution of the elimination of overlapping elements. This approach can effectively eliminate the double counting of materials and equipment in the bill of quantity generation process, thus improving the precision of the bill of quantities. In addition, to optimize the efficiency and accuracy of wall frame-related quantity takeoff. The BIM-based wall framing quantity takeoff (BWFQT) was developed by Khosakitchalert et al. [222]. This method estimates the wall framing in a building by calculating the wall area in the BIM model and determining the average spacing between the individual frames. Moreover, it can be determined from case practice that this wall frame estimation method imposes a minimal memory and performance burden, thus ensuring the overall performance and stability of the BIM.

- Budget estimation

After the bills of quantity are generated through the abovementioned methods, the stakeholders can import the corresponding unit prices into BIM to conduct budget estimation. According to the summarization of Ismail et al. [218], Wong et al. [223], Ying et al. [215], and Zhan et al. [224], the BIM utilization benefits in the cost estimation of rural settlements design and planning stage can be presented in following aspects: The budget appraisal can be provided in the early stage of feasibility study; Conduct the comparison and estimation of the expenditure among multiple designs and layout schemes; Update and reflect the estimated budget timely for all stakeholders as the project progresses and alters. Given comprehensive materials and equipment information repository in BIM utilization, BIM can achieve high-efficiency integration and associated changes in layout planning schemes, materials and devices, expenses, and other modules. When the alterations are conducted in the design and planning process, the bill of quantity and estimated project expenditure could be updated in the BIM applications immediately [225]. Furthermore, to mitigate the deviations in the cost calculation process, Kim et al. [226] estimated the expenditure of materials and devices in targeted projects by adopting two different BIM-based cost estimation frameworks: compositely modeled object (CMO) and individually modeled object (IMO). After outputting the predicted costs for both frameworks, the researcher can neutralize both predicted costs to eliminate the bias and deviations [226].

- Expenditure optimization

From the perspective of expenditure optimization, BIM can reduce project expenditure during their construction, operation and maintenance phases by optimizing the rural settlements' design and planning scheme. Based on the abovementioned environmental analysis and optimization, BIM can improve thermal and light comfort by performing the design and planning of rural settlements according to the local environment and terrain, thus reducing energy consumption expenditure [199,227,228]. In the BIM-based cost calculation application developed by Fazeli et al. [229], BIM is used to estimate and compare the overall cost of each element category (including walls, floors, beams, columns, gates, windows etc.) in different facility schemes to identify the most cost-effective design and planning solutions. Moreover, compared to conventional 2D CAD drawings, BIM omits tedious procedures in their modeling process and can automatically generate bills of quantities, thus decreasing the expenditure of human resources in the design and planning stage.

Moreover, clash detection in the design and planning phase can mitigate the delays and reworks in the further construction phase to decrease unnecessary expenses. Through BIM utilization in the design and planning phase of rural settlements, both hard clashes (multiple objects occupy the same location) and clearance clashes (Conflicts arising from the outreach space of multiple objects) in the BIM models can be identified [29,230]. In the clashes detection and resolution, the clashes are identified and modified through multiple rounds until the conflicts are limited to a tolerable level [231,232]. To reduce unnecessary person-hours expenditure in the design and planning process of rural settlements, the BIM-based clash detection approaches allow the stakeholders to automatically filter out clashes that are not required to be modified by setting a tolerable conflict range and identifying the false positive clashes [37]. In the clash detection process, the stakeholders can utilize the simulation capabilities and visual demonstration in BIM to identify if multiple components cross or pass through each other [233]. Clashes that physically cross each other are considered hard clashes and can be mitigated through manual adjustments or BIM-based automatic correction approaches [231,234]. For components that do not physically intersect but have incompatible parameters with each other (i.e., clearance conflicts), BIM can facilitate the designer in detecting whether the conflict is within the acceptable range and decided to adjust the corresponding clashes or remain intact [235]. Through the integration of Log Logistic Three Parameter (3P) with generalized gamma distributions or the adaptation component-dependent network analysis, the inessential clashes can be precisely excluded to reduce the stakeholders' workload [233,236]. Moreover, machine learning in BIM is another significant character in the clash detection process in rural settlements' design and planning. Through Case-Based Reasoning (CBR) in BIM, the stakeholders can retrieve cases in the case library similar to the target clash and automatically match the clashes with the appropriate solution [129,232,237]. After the clash resolution is completed, the solved clashes are stored as cases in the BIM knowledge repository for future clash detection and resolution [232,238]. This further simplifies the clash detection procedure and reduces its cost.

4. Discussion

Through the systematic review, the BIM capabilities that can be utilized in the design and planning of rural settlements are identified and reviewed in Section 3. In Section 4, the reviewed BIM capabilities are discussed to analyze the benefits, challenges, and future directions of BIM capabilities in rural settlements' design and planning in China.

4.1. Knowledge Management

According to the systematic review results, it can be determined that knowledge management is the fundamental capability of the BIM capabilities in 3D modeling and visualization, disaster prevention and environmental analysis, and cost estimation and optimization (The detailed mutual relationship is presented in Figure 5). From the perspective of 3D modeling, it requires knowledge functions to provide the building structure information, layout information, surrounding conditions and the necessary knowledge assistance in the model establishment process [30,51,93–96,98,102,104,106–108,132,133,239–242]. This knowledge can be retrieved either by importing files, drawings, manually inputted data or through the integration of BIM with third-party devices and software (such as GIS, IoT, sensors, laser scanning, satellite photography, CATIA, Smart city, and so on) [94,98,99,102–108,112,113,144,175]. Based on the research results in Section 3, it can be concluded that efficiency optimization and cost reduction are not mutually exclusive. Gao et al. [243] and Ghaffarianhoseini et al. [29] pointed out in their reviews that it is possible to reduce the workload of stakeholders while increasing the efficiency and accuracy of the information collected through the assistance of third-party equipment and plug-ins in BIM utilization process, thus achieving expenditure conservation and rework mitigations.

Once the information has been captured, it is stored in the BIM data and knowledge repository in IFC or gbXML format according to their belonging category [78–83]. Each element stored in the BIM database has its own unique Global Unique Identifier (GUI) and the applicable information delivery manuals (IDM) to facilitate the subsequent information management and extraction [90,91]. Besides that, through the systematic review of Farzaneh et al. [244] and Wang et al. [245], it can be determined that the IFD (International Framework for Dictionaries) and MVD (Model View Definition) are also essential methods in the information exchange process in BIM application. The IFD can be configured with a unique and proprietary identification for the element. And the MVD can document and classify the specific data exchange process to perform the subsequent information interchange processes conducted to achieve the identical purpose. In the process of BIM utilization in disaster prevention and environmental analysis, knowledge management capabilities can be implemented to integrate the indoor environmental conditions and outdoor layouts of rural settlements in China [171,176,177]. In addition, through GIS, the Internet and weather stations, the BIM-based knowledge management functions can provide the necessary information on the local natural environment, climate, light, temperature, and humidity for each month in the individual rural settlement in China, thus providing the necessary information storage and knowledge support for their disaster prevention and environment analysis [187–191]. These data come from a variety of sources: Information transfer from meteorological, geological, and seismological services; Manual input; Knowledge integration from the Internet of Things; Third-party devices, thermographic imaging technologies, and computational fluid dynamics [114,165,167,180,181,246–249]. Moreover, to perform the cost estimation and optimization in the design and planning phase of rural settlements in China, it is necessary to generate the bill of quantity, perform the cost feasibility studies and expenditure estimation through the knowledge management capabilities in BIM [214–219,221,223].

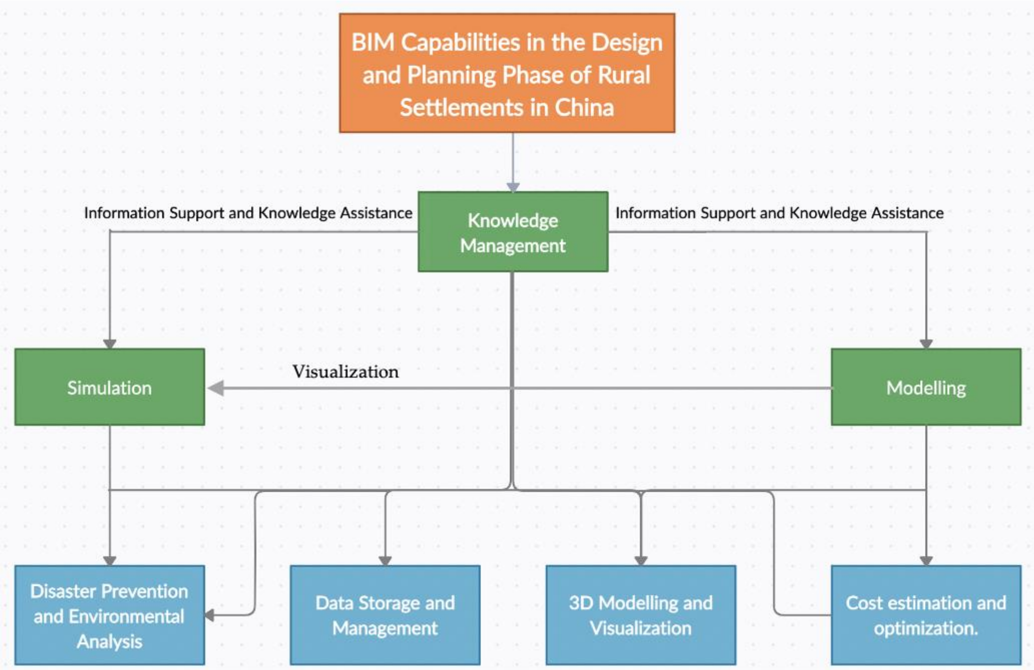

Figure 5. The relationship of different BIM capabilities in the design and planning phase of rural settlements.

In addition, the knowledge management benefits in the design and planning phase can be continued to the construction, operation and maintenance phase of rural settlements in China. In the delivery process between the design, construction, operation and maintenance phases, the documents delivered include the 2D layout drawings and design schemes, 3D project modeling, detailed design procedure, data interaction process, and the inputs and alterations of each individual stakeholder throughout the design and planning phase. Based on the BIM knowledge integration in their design and planning phase, the construction organizations can be familiarized with the entire layout, structures, and each component properties of the entire rural settlements and buildings' interior environment [160,230,250]. Based on these benefits, the stakeholders can effectively estimate the labor, materials, and machinery expenditure during the construction phase, and conduct clash detection and modification [29,37,230–232,236]. In the operation and maintenance process of rural settlements in China, the knowledge delivered from their design and planning phase can provide significant information support and knowledge assistance to the safety/emergence management, maintenance & repair, renovation, and energy management [63,185,251].

Despite the significant benefits of BIM capabilities in the design and planning phase of rural settlements in China, there are still some challenges in the BIM utilization process. The intellectual property right (IPR) issue is a significant barrier in BIM-based knowledge management [29,63]. Given that the rural settlements might be designed and planned through collaboration between various stakeholders, there is the problem of ambiguous IPR [252–254]. Despite all instructions, inputs and changes that each stakeholder makes are automatically recorded in the BIM data repository in the rural settlements' design and planning process [121,255–257]. However, given that participants are usually delegated from multiple departments, it is still challenging to identify the percentage of intellectual property ownership by stakeholders and the boundaries between the various modules of intellectual property [93]. The IPR issue is also acknowledged by multiple literature reviews [253,258–261]. In the design and planning of rural settlements, it is inevitable that stakeholders adopt documents that were restricted by copyright constraints [253]. In addition, insufficient trust in the precision and effectiveness of other participants' outcomes in the collaborative design process can also lead to IPR issues [253]. Moreover, in multi-model or multi-disciplinary projects, the overlapping content between disciplines or models can lead to copyright or contractual issues due to the ambiguity of contractual validity in BIM [253,258,260]. According to the review of Jo et al. [261], it can be identified that potential legal issues in BIM utilization can occur, including: Ownership of BIM models, intellectual property rights, model management conflicts, risk allocation and timelines for deliverables. Although multiple scholars have proposed incorporating digital IPR issues of BIM models into the legal framework through enacting or amendment of relevant legal provisions, there are still significant challenges required to be overcome to achieve the complete resolution of IPR issues [259]. Besides the IPR issue, partial knowledge management capabilities for BIM require the assistance of third-party software and devices, and the diverse formats among software and devices hinder mutual information exchange to some extent [72,262]. Given that partial third-party devices and plug-ins cannot support IFC or gbXML, this barrier impedes their integration with BIM in knowledge management [72].

Given the abovementioned challenges, in future research, it is necessary for the researchers to address IPR issues in the design and planning of rural settlements by improving the definition of demarcation between intellectual property and clarifying the ownership of multiple documents. To solve this issue, some research has been developed. For example, the BIM-based model developed by Lee et al. [131] can assist the 3D BIM model in being partitioned based on the level requested by the stakeholders and provides each partition with the required knowledge [131]. However, to solve the IPR issues thoroughly, other scholars still need to continue to perform their research in this direction. Moreover, to solve the obstacle of mismatched formats among BIM and third-party devices/software, it is necessary to perform systematic reviews to explore and summarize the third-party equipment and software that are required for BIM and can be operated via IFC or gbXML formats.

4.2. Simulation

From the simulation perspective, the literature review results show that the benefits of BIM capabilities in rural settlements' design and planning in China are mainly concentrated on disaster prevention, environmental analysis, and clash detection [171–173]. According to the research results in Section 3, most papers acknowledge the outstanding contributions of BIM to the simulation of the natural environment [192–194,198–200,208,209]. Based on the information on the local environment and climate developed by the knowledge management capabilities in BIM, the BIM simulation applications can simulate the daylight, thermal, and wind environmental conditions of selected rural settlements in China [79,132,187–191,195–197,199,201–204,210–213]. Moreover, certain researchers confirmed that BIM's simulation capabilities play an important role in both simulating the devastation of natural hazards and improving the resilience of rural settlements to disasters [145,171–173,175,177,180,181]. With the integration of the abovementioned simulations and buildings structures in chosen rural settlements, BIM can simulate their resilience to disasters and develop suitable evacuation and optimization schemes [145,174,176–181,183–186]. In the process of environmental simulation, the knowledge management and modeling capabilities in BIM provide essential support to the simulation conduction. Knowledge management provides the necessary information for BIM modeling through the storage of information in the projects' lifecycle and external knowledge support, and BIM modeling enables the detailed visualization of simulation processes and outcomes. As Farzaneh et al. [244] and Hooper [263] concluded in their review, with the development of LOD in the BIM model, the accuracy of environmental simulation and the complexity of 3D visualization is optimized accordingly. Through the simulation capabilities in the rural settlements design and planning phase, BIM can support stakeholders in identifying the most optimized orientation, location, and roof pitch for buildings and infrastructures at the early stage of design and planning. In addition, according to the review of Andriamamonjy et al. [264], the simulation and multi-dimensions visualization capabilities of BIM can facilitate designers to achieve effective improvements to the building facades' structure, beam/column allocation, and the design scheme of windows.

Given that some BIM-based simulation functions require BIM to be integrated with other software, some authors pointed out that the potential insufficient interoperability can lead to significant reductions in the efficiency and accuracy of the simulation [104,265–269]. Insufficient interoperability in the simulation process is one of the most frequently reported causes of information omission [207]. According to the review of Kamel and Memari [39], the lack of uniform standards, information exchange between multiple software or devices, and the absence of solutions for interfacing different simulations under the same model are the main reasons for the insufficient interoperability. Given that partial attributes and symbols in BIM files might not be supported by the simulation software, data omission and semantic misinterpretation are significant challenges during the interaction process [39]. In addition, the mismatch between the different analysis structures required for light, thermal, and ventilation simulations (internal structures, external maintenance structures, or volumes bounded by the center plane of the façade) can also cause hampers in interoperability [39,270]. Therefore, the optimization of the BIM's interoperability with third-party simulation software is an essential research trend for future studies.

Clash detection is deemed the apparent contribution of BIM simulation capabilities by some included studies [271–273]. In the process of BIM utilization in clash detection, BIM can identify the clash generation and utilize machine learning (such as CBR) to automatically match clash solutions to selected clashes [29,37,129,230–233,236,237]. However, some researchers pointed out that the CBR-based clash detection approach is inefficient in identifying complex clashes cases, which makes it challenging to handle clashes with complicated structures [125,274,275]. To solve this issue, BIM simulation functions are deemed as the potential future research directions to over this challenge by some studies [276,277]. Through the simulation capabilities of BIM in the design and planning stages of the rural settlements in China, the potential clashes can be simulated, and the corresponding solutions can be automatically generated [276,277].

4.3. Modeling

According to the research results of this systematic literature review, the modeling capabilities can also provide significant benefits in the design and planning process of rural settlements in China [30,131–133,239–242]. Compared to conventional 2D CAD, Ghaffarianhoseini et al. [29] indicated that BIM can provide superior optimization for spatial visualization, building performance analysis, schedule and project management, and enhanced collaboration between AEC team members through the parametric modeling capabilities in BIM. Through the modeling capabilities in BIM, The overall layout, the interior architecture and the surrounding environment of rural settlements can be demonstrated in the three dimension diorama methods [94,99,134,135,139–141,144,153,155,156]. Furthermore, some researchers pointed out that BIM can generate the required LOD models according to the client's demands, thus achieving the visualization of the internal structure, components, materials and legal boundary of each building in rural settlements in China [105,134–137,158–161]. From the perspective of modeling capabilities in BIM, there are multiple dimension modeling capabilities that can be achieved through BIM, including

3D BIM, 4D BIM, and 5D BIM. According to the review of Cao et al. [51,278,279], 3D BIM can perform the establishment and visualization of the 3-dimensional model to the building and surrounding environment and refines the modeling's accuracy to the required LOD. 4D BIM incorporates the schedule as a dimension into the 3D model, which can then be modelled in 3D to show the status of the project at different stages, thus providing the necessary data support and knowledge assistance for project management, multi-stakeholder collaboration, and clashes detection [139,280,281]. BIM 5D is integrated functions related to project costs and expenses based on BIM 4D, thus assisting stakeholders to perform cost estimation, return-on-investment (ROI) evaluation and expenditure optimization [51,282,283].

Although most researchers acknowledge the essential contributions of BIM's modeling capabilities in design phase of rural settlements in China, some challenges must be overcome. Given the technical threshold of BIM, the design organizations need to provide appropriate BIM training to their staff to enable them to utilize BIM effectively [29,68]. Furthermore, most BIM software that can achieve high-quality modeling capabilities tends to be relatively expensive [28,34,284]. Given the strict budget constraints of most rural design and planning projects in China, some stakeholders are hesitant to adopt BIM [285]. In future studies, research related to the simplification, low threshold, and ease of adaptation of BIM software is recommended to become the future research direction.

5. Conclusions

In the context of rural revitalization, rural settlements are receiving significant attention from all over China. The Chinese government has announced its intention to gradually improve the amenities and public services in rural settlements and enhance the living environment, quality of buildings and residential comfort in rural settlements in China [286]. However, compared to the urban, the environmental conditions, and residential comfort of rural settlements in China are relatively backward. As a multi-function method, BIM can provide remarkable improvements to rural settlements in China. Through BIM capabilities in the design and planning phase of rural settlements in China, the environmental condition, buildings' quality, and residential comfort can be significantly optimized.

Despite the significant contribution of BIM, there are still insufficient cases of BIM being applied to the design and planning phase of rural settlements in China. One significant barrier is the insufficient familiarity with the BIM capabilities in the design and planning of the rural settlements. To prompt the BIM utilization in the rural settlements' design and planning, this study aims to perform a systematic review of the BIM capabilities in the design and planning phase of rural settlements in China. Through the systematic literature review, it can be identified that BIM capabilities can be utilized in the rural settlements' design and planning phase in the following aspects: Data storage and management; 3D modeling and visualization; Disaster prevention and environmental analysis; Cost estimation and optimization.

Through the discussion and analysis of the literature review results, it can be concluded that BIM is utilized in the design and planning phase of rural settlements in China based on their capabilities in three perspectives: knowledge management, simulation, and modeling. From the perspective of knowledge management capabilities, BIM can provide stakeholders with information support and knowledge assistance with the required LOD (level of detail) throughout the entire design and planning phase of rural settlements. Through the integration of BIM with third-party devices, BIM can also effectively provide information on the natural environment (e.g., location, topography, climate, hydrology, vegetation) and support the infrastructure layout of rural settlements and their surrounding areas. Based on the uniform document storage format (IFC or gbXML), BIM's knowledge management capabilities can complete seamless information exchange between multiple platforms, and the data collected and generated throughout the design & planning phases can be integrated and delivered to the construction, operation and maintenance phases of corresponding rural settlements. In the aspect of modeling and visualization, through the integration of BIM with third-party equipment and software (e.g., sensors, GIS, satellites, cameras, RFID, IoT), BIM can achieve multiple LOD modeling and visualization of buildings, structures, legal boundary and their surroundings throughout the design and planning stage of rural settlement. Based on the information foundation provided by BIM knowledge management capabilities, through the integration of local environmental information and climate data, BIM can be utilized to perform their simulation capabilities to identify potential hazards, formulate disaster prevention and mitigation schemes based on the established rural settlement model. Furthermore, based on the above-mentioned functions and sensor-related assistance, daylight environment analysis, thermal environment evaluation, and computational fluid dynamics can be effectively performed by simulation capabilities in BIM. From the viewpoint of cost estimation and optimization, based on the design solutions of rural settlements stored and managed in BIM, stakeholders can utilize BIM to automatically generate bills of quantities and perform budget estimation and expenditure optimization. Moreover, clash detection in the rural settlements' design and planning phase can be conducted through BIM's multi-dimensions modeling, visualization, and simulation capabilities.

In addition to the abovementioned benefits, the challenges of BIM utilization in the design and planning phase of rural settlements in China are also revealed in this study, including: Insufficient interoperability; Ambiguous intellectual property rights (IPR); Defective complex clashes detection; High expenditure on BIM software purchases and operators training. Furthermore, the future research directions of BIM capabilities in the design and planning of rural settlements in China are also developed in Section 4. The research results in this systematic review can significantly improve the familiarity of stakeholders with the BIM capabilities in the design and planning process of rural settlements in China to optimize the layout, environment, construction quality, and residential comfort of rural settlements in China.

There is some limitation in this study that are welcome to be addressed by other scholars through their research:

A. Due to the restriction of the research aim, this study only reviews and discusses the BIM capabilities that can be utilized in the design and planning phase of rural settlements in China.
B. Given the limitation of the authors' language skills, only English articles are reviewed in this study. The articles written in non-English are excluded from the article screen process.
C. To guarantee the reviewed articles were quality, only articles that could be retrieved in WoS and Scopus databases were contained in this study. This regulation might cause the omission of some BIM functions.

To solve the abovementioned limitations, other scholars are welcome to explore the BIM capabilities that can be utilized in the construction, renovation, and facility management of rural settlements in China. Given that some countries have similar national conditions to China (such as Vietnam), based on the research results of this study, other scholars can perform the corresponding systematic review to explore the BIM capabilities that can be applied to rural settlements' design and planning in other countries.

Based on the research results in this study, it can be determined that BIM utilization is an important trend in the design and planning of rural settlements in China. To optimize the BIM utilization in the design and planning phase of rural settlements in China, the following research directions are necessary to be attached importance by other researchers in their future studies: Knowledge retrieval and management in BIM throughout the life cycle of rural settlements; Interoperability between BIM and third-party devices; BIM-based environmental simulation; BIM-based disaster monitoring and prevention; Clash detection and elimination based on BIM; Sustainable design through BIM capabilities.

Author Contributions: Y.C. wrote the original draft preparation and conducted data curation and formal analysis; Y.C., L.H., S.N.K. and N.M.A. were responsible for the review and conceptualization;

L.H. and N.M.A. were responsible for the supervision. All authors have read and agreed to the published version of the manuscript.

Funding: This project was funded by the "Outstanding Young Talents from Universities Visiting and Studying at Inland and Abroad Project (Project Type: Provincial; Project No.: gxgnfx2019047; Project Sponsor: Liyan Huang)".

Data Availability Statement: Not applicable.

Acknowledgments: I would first like to thank Syahrul Nizam Kamaruzzaman and Nur Mardhiyah Aziz. Your insightful guidance and constructive feedback pushed me to sharpen my thinking and brought my work to a higher level. Moreover, I would like to acknowledge Mingru Cao, Yan Zhang and Yuehua Ma. Your constructive suggestions and warm-hearted psychic support sustained me in completing this study.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Supreme People's Court. *Opinions of the Supreme People's Court on Providing Judicial Services and Guarantees for Comprehensively Promoting Rural Revitalization and Accelerating the Modernization of Agriculture and Rural Areas*; Supreme People's Court: Beijing, China, 2021; Vol. No. 23 [2021] of the Supreme People's Court.
2. Chen, M.; Zhou, Y.; Huang, X.; Ye, C. The Integration of New-Type Urbanization and Rural Revitalization Strategies in China: Origin, Reality and Future Trends. *Land* **2021**, *10*, 207. [CrossRef]
3. Zeng, X.; Zhao, Y.; Cheng, Z. Development and Research of Rural Renewable Energy Management and Ecological Management Information System under the Background of Beautiful Rural Revitalization Strategy. *Sustain. Comput. Inform. Syst.* **2021**, *30*, 100553. [CrossRef]
4. Ye, C.; Chen, M.; Chen, R.; Liao, C. Rural-Urban Governance toward Sustainable Development Goals. *J. Geogr. Sci.* **2022**, *32*, 1405–1408. [CrossRef]
5. Hou, D.; Wang, X. Measurement of Agricultural Green Development Level in the Three Provinces of Northeast China under the Background of Rural Vitalization Strategy. *Front. Public Health* **2022**, *10*, 824202. [CrossRef]
6. Jiang, Y.; Long, H.; Tang, Y.; Deng, W.; Chen, K.; Zheng, Y. The Impact of Land Consolidation on Rural Vitalization at Village Level: A Case Study of a Chinese Village. *J. Rural Stud.* **2021**, *86*, 485–496. [CrossRef]
7. Jiang, Y.; Long, H.; Ives, C.D.; Deng, W.; Chen, K.; Zhang, Y. Modes and Practices of Rural Vitalisation Promoted by Land Consolidation in a Rapidly Urbanising China: A Perspective of Multifunctionality. *Habitat Int.* **2022**, *121*, 102514. [CrossRef]
8. Ling, W.; Dong, J.F. Rural Vitalization-Oriented Suitability Evaluation Index for Green Technologies of Rural Housing in Northeast China. *IOP Conf. Ser. Earth Environ. Sci.* **2018**, *188*, 012113. [CrossRef]
9. Lu, M.; Wei, L.; Ge, D.; Sun, D.; Zhang, Z.; Lu, Y. Spatial Optimization of Rural Settlements Based on the Perspective of Appropriateness–Domination: A Case of Xinyi City. *Habitat Int.* **2020**, *98*, 102148. [CrossRef]
10. Yurui, L.; Luyin, Q.; Qianyi, W.; Karácsonyi, D. Towards the Evaluation of Rural Livability in China: Theoretical Framework and Empirical Case Study. *Habitat Int.* **2020**, *105*, 102241. [CrossRef]
11. Liu, Y.; Li, Y. Revitalize the World's Countryside. *Nature* **2017**, *548*, 275–277. [CrossRef] [PubMed]
12. Shi, J.; Yang, X. Sustainable Development Levels and Influence Factors in Rural China Based on Rural Revitalization Strategy. *Sustainability* **2022**, *14*, 8908. [CrossRef]
13. Gao, T.; Ivolga, A.; Erokhin, V. Sustainable Rural Development in Northern China: Caught in a Vice between Poverty, Urban Attractions, and Migration. *Sustainability* **2018**, *10*, 1467. [CrossRef]
14. Chen, J.; Yang, T.; Wang, Y.; Jiang, H.; He, C. Effects of Ecological Restoration on Water Quality and Benthic Macroinvertebrates in Rural Rivers of Cold Regions: A Case Study of the Huaide River, Northeast China. *Ecol. Indic.* **2022**, *142*, 109169. [CrossRef]
15. Qian, M.; Cheng, Z.; Wang, Z.; Qi, D. What Affects Rural Ecological Environment Governance Efficiency? *Evidence from China. IJERPH* **2022**, *19*, 5925. [CrossRef] [PubMed]
16. Wang, J.; Li, B.; Yu, W.; Yang, Q.; Wang, H.; Huang, D.; Sundell, J.; Norbäck, D. Rhinitis Symptoms and Asthma among Parents of Preschool Children in Relation to the Home Environment in Chongqing, China. *PLoS ONE* **2014**, *9*, e94731. [CrossRef]
17. Zhou, J. Status, Causes and Countermeasures of Environmental Pollution in China's Rural Tourism Development. *Nat. Environ. Pollut. Technol.* **2018**, *17*, 543–549.
18. National Bureau of Statistics of China. *China Statistical Yearbook 2021*; China Statistics Press: Beijing, China, 2022.
19. National Bureau of Statistics of China. *China Rural Statistical Yearbook*; China Statistics Press: Beijing, China, 2022.
20. Song, Y. Is the Countryside Really Falling Behind under the Tide of Urbanization? *Urban Environ. Stud.* **2016**, *03*, 3–19.
21. Feng, B.; Hu, M.H. Study on Ecological Environment Protection and Sustainable Development Strategy in Characteristic Rural Areas. *AMR* **2012**, *616–618*, 1383–1387. [CrossRef]
22. Li, Y. Study on Rural Ecological Environment Pollution and Environmental Protection Countermeasures Based on Air Pollution Index. *IOP Conf. Ser. Earth Environ. Sci.* **2020**, *450*, 012105. [CrossRef]

23. Peng, Y. Study on Sources, Causes and Countermeasures of Water Pollution in Rural Areas of Guangxi in China. *Nat. Environ. Pollut. Technol.* **2017**, *16*, 1235–1241.
24. Wu, B.; Mu, D.; Luo, Y.; Xiao, Z.; Zhao, J.; Cui, D. Rural Ecological Problems in China from 2013 to 2022: A Review of Research Hotspots, Geographical Distribution, and Countermeasures. *Land* **2022**, *11*, 1326. [CrossRef]
25. Yuan, J.; Guo, X. The Synergistic Relationship between Rural Environmental Pollution and Industrial Structural Change in Heilongjiang, China. *Nat. Environ. Pollut. Technol.* **2016**, *15*, 521.
26. *ISO 19650-1:2018*; Organization and Digitization of Information about Buildings and Civil Engineering Works, Including Building Information Modelling (BIM)—Information Management Using Building Information Modelling. British Standards Institution: London, UK, 2018.
27. National Bureau of Statistics of China. *NBS National BIM Report 2019*; National Bureau of Statistics of China: Beijing, China, 2019.
28. Chan, D.W.M.; Olawumi, T.O.; Ho, A.M.L. Perceived Benefits of and Barriers to Building Information Modelling (BIM) Implementation in Construction: The Case of Hong Kong. *J. Build. Eng.* **2019**, *25*, 100764. [CrossRef]
29. Ghaffarianhoseini, A.; Tookey, J.; Ghaffarianhoseini, A.; Naismith, N.; Azhar, S.; Efimova, O.; Raahemifar, K. Building Information Modelling (BIM) Uptake: Clear Benefits, Understanding Its Implementation, Risks and Challenges. *Renew. Sustain. Energy Rev.* **2017**, *75*, 1046–1053. [CrossRef]
30. Huang, B.; Lei, J.; Ren, F.; Chen, Y.; Zhao, Q.; Li, S.; Lin, Y. Contribution and Obstacle Analysis of Applying BIM in Promoting Green Buildings. *J. Clean. Prod.* **2021**, *278*, 123946. [CrossRef]
31. Toukola, S.; Ahola, T. Digital Tools for Stakeholder Participation in Urban Development Projects. *Proj. Leadersh. Soc.* **2022**, *3*, 100053. [CrossRef]
32. Ding, Z.; Liu, S.; Liao, L.; Zhang, L. A Digital Construction Framework Integrating Building Information Modeling and Reverse Engineering Technologies for Renovation Projects. *Autom. Constr.* **2019**, *102*, 45–58. [CrossRef]
33. Blay, K.B.; Tuuli, M.M.; France-Mensah, J. Managing Change in BIM-Level 2 Projects: Benefits, Challenges, and Opportunities. *BEPAM* **2019**, *9*, 581–596. [CrossRef]
34. Zakari, Z.; Ali, N.M.A.; Haron, A.T.; Ponting, A.M.; Hamid, Z.A. Exploring the Barriers and Driving Factors in Implementing Building Information Modelling (BIM) in the Malaysian Construction Industry: A Preliminary Study. *J. Inst. Eng. Malays.* **2014**, *75*, 1–10. [CrossRef]
35. Olawumi, T.O.; Chan, D.W.M. Identifying and Prioritizing the Benefits of Integrating BIM and Sustainability Practices in Construction Projects: A Delphi Survey of International Experts. *Sustain. Cities Soc.* **2018**, *40*, 16–27. [CrossRef]
36. Zhang, L.; Chu, Z.; He, Q.; Zhai, P. Investigating the Constraints to Buidling Information Modeling (BIM) Applications for Sustainable Building Projects: A Case of China. *Sustainability* **2019**, *11*, 1896. [CrossRef]
37. Akhmetzhanova, B.; Nadeem, A.; Hossain, M.A.; Kim, J.R. Clash Detection Using Building Information Modeling (BIM) Technology in the Republic of Kazakhstan. *Buildings* **2022**, *12*, 102. [CrossRef]
38. Tatygulov, A.; Gizatulina, A.; Zhamankulov, A. Level of BIM Development and Applying in Design and Engineering Survey Companies in the Republic of Kazakhstan. *Research Results. Bull. Natl. Eng. Acad. Repub. Kazakhstan* **2020**, *4*, 100–106.
39. Kamel, E.; Memari, A.M. Review of BIM's Application in Energy Simulation: Tools, Issues, and Solutions. *Autom. Constr.* **2019**, *97*, 164–180. [CrossRef]
40. Pezeshki, Z.; Soleimani, A.; Darabi, A. Application of BEM and Using BIM Database for BEM: A Review. *J. Build. Eng.* **2019**, *23*, 1–17. [CrossRef]
41. Kim, S.; Bhat, A.; Poirier, E.A.; Staub-French, S. Investigating Owner Requirements for BIM-Enabled Design Review. In Proceedings of the Construction Research Congress 2018, New Orleans, LA, USA, 2–4 April 2018; American Society of Civil Engineers: New Orleans, LA, USA, 2018; pp. 581–590.
42. Dowsett, R.; Harty, C. Evaluating the Benefits of BIM for Sustainable Design–A Review. In Proceedings of the 29th Annual ARCOM conference, Reading, UK, 2–4 September 2013; pp. 13–23.
43. Dong, J.Y.; Cheng, W.; Ma, C.P.; Xin, L.S.; Tan, Y.T. Thermal Environment Analysis and Energy Conservation Research of Rural Residence in Cold Regions of China Based on BIM Platform. *IOP Conf. Ser. Earth Environ. Sci.* **2017**, *69*, 012009. [CrossRef]
44. Jia, J.; Sun, J.; Wang, Z.; Xu, T. The Construction of BIM Application Value System for Residential Buildings' Design Stage in China Based on Traditional DBB Mode. *Procedia Eng.* **2017**, *180*, 851–858. [CrossRef]
45. Matejka, P. Utilization of Digitized Building Data and Information Models (BIM) in Value Estimation of Building in Rural Areas. In Proceedings of the Engineering for Rural Development, Jelgava, Latvia, 22–24 May 2019.
46. Mihindu, S.; Arayici, Y. Digital Construction through BIM Systems Will Drive the Re-Engineering of Construction Business Practices. In Proceedings of the 2008 International Conference Visualisation, London, UK, 9–11 July 2008; IEEE: Piscataway, NJ, USA, 2008; pp. 29–34.
47. Veeraraghavan, S.; Krishnaswamy, P. A Novel Technology Based Framework to Address Global Humanitarian Issues. In Proceedings of the 2011 IEEE Global Humanitarian Technology Conference, Seattle, WA, USA, 30 October–1 November 2011; IEEE: Piscataway, NJ, USA, 2011; pp. 338–343.
48. Cook, D.J. Systematic Reviews: Synthesis of Best Evidence for Clinical Decisions. *Ann. Intern. Med.* **1997**, *126*, 376. [CrossRef]
49. Harris, J.D.; Quatman, C.E.; Manring, M.M.; Siston, R.A.; Flanigan, D.C. How to Write a Systematic Review. *Am. J. Sport. Med.* **2014**, *42*, 2761–2768. [CrossRef]
50. Xiao, Y.; Watson, M. Guidance on Conducting a Systematic Literature Review. *J. Plan. Educ. Res.* **2019**, *39*, 93–112. [CrossRef]

51. Cao, Y.; Kamaruzzaman, S.N.; Aziz, N.M. Green Building Construction: A Systematic Review of BIM Utilization. *Buildings* **2022**, *12*, 1205. [CrossRef]
52. Mulrow, C.D. Systematic Reviews: Rationale for Systematic Reviews. *BMJ* **1994**, *309*, 597–599. [CrossRef]
53. Munn, Z.; Peters, M.D.; Stern, C.; Tufanaru, C.; McArthur, A.; Aromataris, E. Systematic Review or Scoping Review? Guidance for Authors When Choosing between a Systematic or Scoping Review Approach. *BMC Med. Res. Methodol.* **2018**, *18*, 1–7. [CrossRef] [PubMed]
54. Pearson, A. Balancing the Evidence: Incorporating the Synthesis of Qualitative Data into Systematic Reviews. *JBI Rep.* **2004**, *2*, 45–64. [CrossRef]
55. Pittaway, L.; Cope, J. Entrepreneurship Education: A Systematic Review of the Evidence. *Int. Small Bus. J.* **2007**, *25*, 479–510. [CrossRef]
56. Yigitcanlar, T.; Desouza, K.C.; Butler, L.; Roozkhosh, F. Contributions and Risks of Artificial Intelligence (AI) in Building Smarter Cities: Insights from a Systematic Review of the Literature. *Energies* **2020**, *13*, 1473. [CrossRef]
57. Leclercq, V.; Beaudart, C.; Ajamieh, S.; Rabenda, V.; Tirelli, E.; Bruyère, O. Meta-Analyses Indexed in PsycINFO Had a Better Completeness of Reporting When They Mention PRISMA. *J. Clin. Epidemiol.* **2019**, *115*, 46–54. [CrossRef]
58. Page, M.J.; McKenzie, J.E.; Bossuyt, P.M.; Boutron, I.; Hoffmann, T.C.; Mulrow, C.D.; Shamseer, L.; Tetzlaff, J.M.; Akl, E.A.; Brennan, S.E.; et al. The PRISMA 2020 Statement: An Updated Guideline for Reporting Systematic Reviews. *Syst. Rev.* **2021**, *10*, 89. [CrossRef]
59. Rethlefsen, M.L.; Page, M.J. PRISMA 2020 and PRISMA-S: Common Questions on Tracking Records and the Flow Diagram. *JMLA* **2021**, *110*, 253–257. [CrossRef]
60. Al-Emran, M.; Mezhuyev, V.; Kamaludin, A.; Shaalan, K. The Impact of Knowledge Management Processes on Information Systems: A Systematic Review. *Int. J. Inf. Manag.* **2018**, *43*, 173–187. [CrossRef]
61. Ali, O.; Shrestha, A.; Soar, J.; Wamba, S.F. Cloud Computing-Enabled Healthcare Opportunities, Issues, and Applications: A Systematic Review. *Int. J. Inf. Manag.* **2018**, *43*, 146–158. [CrossRef]
62. Borges, A.F.S.; Laurindo, F.J.B.; Spínola, M.M.; Gonçalves, R.F.; Mattos, C.A. The Strategic Use of Artificial Intelligence in the Digital Era: Systematic Literature Review and Future Research Directions. *Int. J. Inf. Manag.* **2021**, *57*, 102225. [CrossRef]
63. Cao, Y.; Kamaruzzaman, S.N.; Aziz, N.M. Building Information Modeling (BIM) Capabilities in the Operation and Maintenance Phase of Green Buildings: A Systematic Review. *Buildings* **2022**, *12*, 830. [CrossRef]
64. Gupta, S.; Kar, A.K.; Baabdullah, A.; Al-Khowaiter, W.A. Big Data with Cognitive Computing: A Review for the Future. *Int. J. Inf. Manag.* **2018**, *42*, 78–89. [CrossRef]
65. Lepenioti, K.; Bousdekis, A.; Apostolou, D.; Mentzas, G. Prescriptive Analytics: Literature Review and Research Challenges. *Int. J. Inf. Manag.* **2020**, *50*, 57–70. [CrossRef]
66. Cao, Y.; Xu, C.; Kamaruzzaman, S.N.; Aziz, N.M. A Systematic Review of Green Building Development in China: Advantages, Challenges and Future Directions. *Sustainability* **2022**, *14*, 12293. [CrossRef]
67. Pereira, V.; Santos, J.; Leite, F.; Escórcio, P. Using BIM to Improve Building Energy Efficiency—A Scientometric and Systematic Review. *Energy Build.* **2021**, *250*, 111292. [CrossRef]
68. Regona, M.; Yigitcanlar, T.; Xia, B.; Li, R.Y.M. Opportunities and Adoption Challenges of AI in the Construction Industry: A PRISMA Review. *JOItmC* **2022**, *8*, 45. [CrossRef]
69. Semeraro, C.; Lezoche, M.; Panetto, H.; Dassisti, M. Digital Twin Paradigm: A Systematic Literature Review. *Comput. Ind.* **2021**, *130*, 103469. [CrossRef]
70. Deshpande, A.; Azhar, S.; Amireddy, S. A Framework for a BIM-Based Knowledge Management System. *Procedia Eng.* **2014**, *85*, 113–122. [CrossRef]
71. Ding, Z.; Zheng, K.; Tan, Y. BIM Research vs BIM Practice: A Bibliometric-Qualitative Analysis from China. *ECAM* **2021**, 28. [CrossRef]
72. Wang, H.; Meng, X. Transformation from IT-Based Knowledge Management into BIM-Supported Knowledge Management: A Literature Review. *Expert Syst. Appl.* **2019**, *121*, 170–187. [CrossRef]
73. Wang, L.; Leite, F. Process Knowledge Capture in BIM-Based Mechanical, Electrical, and Plumbing Design Coordination Meetings. *J. Comput. Civ. Eng.* **2016**, *30*, 04015017. [CrossRef]
74. Lu, Y.; Wu, Z.; Chang, R.; Li, Y. Building Information Modeling (BIM) for Green Buildings: A Critical Review and Future Directions. *Autom. Constr.* **2017**, *83*, 134–148. [CrossRef]
75. Ding, L.; Xu, X. Application of Cloud Storage on BIM Life-Cycle Management. *Int. J. Adv. Robot. Syst.* **2014**, *11*, 129. [CrossRef]
76. Aziz, Z.; Riaz, Z.; Arslan, M. Leveraging BIM and Big Data to Deliver Well Maintained Highways. *Facilities* **2017**, *35*, 818–832. [CrossRef]
77. Gledson, B.J.; Greenwood, D. The Adoption of 4D BIM in the UK Construction Industry: An Innovation Diffusion Approach. *ECAM* **2017**, *24*, 950–967. [CrossRef]
78. Bastos Porsani, G.; Del Valle de Lersundi, K.; Sánchez-Ostiz Gutiérrez, A.; Fernández Bandera, C. Interoperability between Building Information Modelling (BIM) and Building Energy Model (BEM). *Appl. Sci.* **2021**, *11*, 2167. [CrossRef]
79. Ham, Y.; Golparvar-Fard, M. Mapping Actual Thermal Properties to Building Elements in GbXML-Based BIM for Reliable Building Energy Performance Modeling. *Autom. Constr.* **2015**, *49*, 214–224. [CrossRef]

80. Kim, H.; Kim, J. A Case-Based Reasoning Model for Retrieving Window Replacement Costs through Industry Foundation Class. *Appl. Sci.* **2019**, *9*, 4728. [CrossRef]
81. Mirahadi, F.; McCabe, B.; Shahi, A. IFC-Centric Performance-Based Evaluation of Building Evacuations Using Fire Dynamics Simulation and Agent-Based Modeling. *Autom. Constr.* **2019**, *101*, 1–16. [CrossRef]
82. Shalabi, F.; Turkan, Y. IFC BIM-Based Facility Management Approach to Optimize Data Collection for Corrective Maintenance. *J. Perform. Constr. Facil.* **2017**, *31*, 04016081. [CrossRef]
83. Zhuang, D.; Zhang, X.; Lu, Y.; Wang, C.; Jin, X.; Zhou, X.; Shi, X. A Performance Data Integrated BIM Framework for Building Life-Cycle Energy Efficiency and Environmental Optimization Design. *Autom. Constr.* **2021**, *127*, 103712. [CrossRef]
84. Bansal, V.K. Integrated Framework of BIM and GIS Applications to Support Building Lifecycle: A Move toward ND Modeling. *J. Archit. Eng.* **2021**, *27*, 05021009. [CrossRef]
85. Grytting, I.; Svalestuen, F.; Lohne, J.; Sommerseth, H.; Augdal, S.; Lædre, O. Use of LoD Decision Plan in BIM-Projects. *Procedia Eng.* **2017**, *196*, 407–414. [CrossRef]
86. Tolmer, C.-E.; Castaing, C.; Diab, Y.; Morand, D. Adapting LOD Definition to Meet BIM Uses Requirements and Data Modeling for Linear Infrastructures Projects: Using System and Requirement Engineering. *Vis. Eng.* **2017**, *5*, 21. [CrossRef]
87. Liu, H.; Xie, L.; Shi, L.; Hou, M.; Li, A.; Hu, Y. A Method of Automatic Extraction of Parameters of Multi-LoD BIM Models for Typical Components in Wooden Architectural-Heritage Structures. *Adv. Eng. Inform.* **2019**, *42*, 101002. [CrossRef]
88. Beach, T.; Petri, I.; Rezgui, Y.; Rana, O. Management of Collaborative BIM Data by Federating Distributed BIM Models. *J. Comput. Civ. Eng.* **2017**, *31*, 04017009. [CrossRef]
89. Van Gassel, F.J.M.; Láscaris-Comneno, T.; Maas, G.J. The Conditions for Successful Automated Collaboration in Construction. *Autom. Constr.* **2014**, *39*, 85–92. [CrossRef]
90. Alreshidi, E.; Mourshed, M.; Rezgui, Y. Requirements for Cloud-Based BIM Governance Solutions to Facilitate Team Collaboration in Construction Projects. *Requir. Eng.* **2018**, *23*, 1–31. [CrossRef]
91. Singh, V.; Gu, N.; Wang, X. A Theoretical Framework of a BIM-Based Multi-Disciplinary Collaboration Platform. *Autom. Constr.* **2011**, *20*, 134–144. [CrossRef]
92. Kalasapudi, V.S.; Turkan, Y.; Tang, P. Toward Automated Spatial Change Analysis of MEP Components Using 3D Point Clouds and As-Designed BIM Models. In Proceedings of the 2014 2nd International Conference on 3D Vision, Tokyo, Japan, 8–11 December 2014; IEEE: Piscataway, NJ, USA, 2014; Volume 2, pp. 145–152.
93. Atazadeh, B.; Halalkhor Mirkalaei, L.; Olfat, H.; Rajabifard, A.; Shojaei, D. Integration of Cadastral Survey Data into Building Information Models. *Geo-Spat. Inf. Sci.* **2021**, *24*, 387–402. [CrossRef]
94. Celeste, G.; Lazoi, M.; Mangia, M.; Mangialardi, G. Innovating the Construction Life Cycle through BIM/GIS Integration: A Review. *Sustainability* **2022**, *14*, 766. [CrossRef]
95. Park, J.; Cai, H.; Dunston, P.S.; Ghasemkhani, H. Database-Supported and Web-Based Visualization for Daily 4D BIM. *J. Constr. Eng. Manag.* **2017**, *143*, 04017078. [CrossRef]
96. Teizer, J.; Wolf, M.; Golovina, O.; Perschewski, M.; Propach, M.; Neges, M.; König, M. Internet of Things (IoT) for Integrating Environmental and Localization Data in Building Information Modeling (BIM). In Proceedings of the International Symposium on Automation and Robotics in Construction ISARCT, Taipei, Taiwan, 28 June–1 July 2017; IAARC Publications: Taipei, China, 2017; Volume 34.
97. Chen, C.-J.; Chen, S.; Li, S.; Chiu, H. Green BIM-Based Building Energy Performance Analysis. *Comput.-Aided Des. Appl.* **2017**, *14*, 650–660. [CrossRef]
98. Liu, X.; Wang, X.; Wright, G.; Cheng, J.; Li, X.; Liu, R. A State-of-the-Art Review on the Integration of Building Information Modeling (BIM) and Geographic Information System (GIS). *IJGI* **2017**, *6*, 53. [CrossRef]
99. Ma, Z.; Ren, Y. Integrated Application of BIM and GIS: An Overview. *Procedia Eng.* **2017**, *196*, 1072–1079. [CrossRef]
100. Cui, B.; Wen, X.; Zhang, D. The Application of Intelligent Emergency Response System for Urban Underground Space Disasters Based on 3D GIS, BIM and Internet of Things. In Proceedings of the 2019 International Conference on Artificial Intelligence and Computer Science, Wuhan, China, 12–13 July 2019; ACM: New York, NY, USA, 2019; pp. 745–749.
101. Du, H.; Du, J.; Huang, S. GIS, GPS, and BIM-Based Risk Control of Subway Station Construction. In Proceedings of the ICTE 2015, Dailan, China, 26–27 September 2015; American Society of Civil Engineers: Reston, VA, USA, 2015; pp. 1478–1485.
102. Kang, T.W.; Hong, C.H. A Study on Software Architecture for Effective BIM/GIS-Based Facility Management Data Integration. *Autom. Constr.* **2015**, *54*, 25–38. [CrossRef]
103. Marzouk, M.; Othman, A. Planning Utility Infrastructure Requirements for Smart Cities Using the Integration between BIM and GIS. *Sustain. Cities Soc.* **2020**, *57*, 102120. [CrossRef]
104. Sani, M.J.; Rahman, A.A. GIS and BIM Integration at Data Level: A Review. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* **2018**, *42*, 299–306. [CrossRef]
105. Sun, J.; Mi, S.; Olsson, P.O.; Paulsson, J.; Harrie, L. Utilizing BIM and GIS for Representation and Visualization of 3D Cadastre. *IJGI* **2019**, *8*, 503. [CrossRef]
106. Ding, X.; Yang, J.; Liu, L.; Huang, W.; Wu, P. Integrating IFC and CityGML Model at Schema Level by Using Linguistic and Text Mining Techniques. *IEEE Access* **2020**, *8*, 56429–56440. [CrossRef]
107. Kardinal Jusuf, S.; Mousseau, B.; Godfroid, G.; Soh Jin Hui, V. Integrated Modeling of CityGML and IFC for City/Neighborhood Development for Urban Microclimates Analysis. *Energy Procedia* **2017**, *122*, 145–150. [CrossRef]

108. Stouffs, R.; Tauscher, H.; Biljecki, F. Achieving Complete and Near-Lossless Conversion from IFC to CityGML. *Int. J. Geo-Inf.* **2018**, *7*, 355. [CrossRef]
109. Pepe, M.; Costantino, D.; Alfio, V.S.; Restuccia, A.G.; Papalino, N.M. Scan to BIM for the Digital Management and Representation in 3D GIS Environment of Cultural Heritage Site. *J. Cult. Herit.* **2021**, *50*, 115–125. [CrossRef]
110. Tsilimantou, E.; Delegou, E.T.; Nikitakos, I.A.; Ioannidis, C.; Moropoulou, A. GIS and BIM as Integrated Digital Environments for Modeling and Monitoring of Historic Buildings. *Appl. Sci.* **2020**, *10*, 1078. [CrossRef]
111. Mignard, C.; Nicolle, C. Merging BIM and GIS Using Ontologies Application to Urban Facility Management in ACTIVe3D. *Comput. Ind.* **2014**, *65*, 1276–1290. [CrossRef]
112. Cesconetto, J.; Augusto Silva, L.; Bortoluzzi, F.; Navarro-Cáceres, M.; Zeferino, C.A.; Leithardt, V.R.Q. PRIPRO—Privacy Profiles: User Profiling Management for Smart Environments. *Electronics* **2020**, *9*, 1519. [CrossRef]
113. Hossein Motlagh, N.; Khatibi, A.; Aslani, A. Toward Sustainable Energy-Independent Buildings Using Internet of Things. *Energies* **2020**, *13*, 5954. [CrossRef]
114. Tang, S.; Shelden, D.R.; Eastman, C.M.; Pishdad-Bozorgi, P.; Gao, X. A Review of Building Information Modeling (BIM) and the Internet of Things (IoT) Devices Integration: Present Status and Future Trends. *Autom. Constr.* **2019**, *101*, 127–139. [CrossRef]
115. Qian, H. Design of Tunnel Automatic Monitoring System Based on BIM and IOT. *J. Phys. Conf. Ser.* **2021**, *1982*, 012073. [CrossRef]
116. Shahinmoghadam, M.; Motamedi, A. Review of BIM-Centred IoT Deployment–State of the Art, Opportunities, and Challenges. In Proceedings of the 36th International Symposium on Automation and Robotics in Construction (ISARC 2019), Banff, AB, Canada, 21–24 May 2019; pp. 1268–1275.
117. Chang, K.-M.; Dzeng, R.-J.; Wu, Y.-J. An Automated IoT Visualization BIM Platform for Decision Support in Facilities Management. *Appl. Sci.* **2018**, *8*, 1086. [CrossRef]
118. Natephra, W.; Motamedi, A. Live Data Visualization of IoT Sensors Using Augmented Reality (AR) and BIM. In Proceedings of the 36th International Symposium on Automation and Robotics in Construction (ISARC 2019), Banff, AB, Canada, 21–24 May 2019.
119. Yuan, Y.; Yang, J.; Shao, R.; Mao, J.; Zhang, C. Research on BIM Model Lightweighting Methods and IoT Technology Application in the Context of WebGL. *J. Phys. Conf. Ser.* **2022**, *2215*, 012008. [CrossRef]
120. Al-Ashmori, Y.Y.; Othman, I.; Rahmawati, Y.; Amran, Y.H.M.; Sabah, S.H.A.; Rafindadi, A.D.; Mikić, M. BIM Benefits and Its Influence on the BIM Implementation in Malaysia. *Ain Shams Eng. J.* **2020**, *11*, 1013–1019. [CrossRef]
121. Wang, H.; Meng, X. BIM-Supported Knowledge Management: Potentials and Expectations. *J. Manag. Eng.* **2021**, *37*, 04021032. [CrossRef]
122. Cavieres, A.; Bhatia, U.; Joshi, P.; Zhao, F.; Ram, A. CBArch: A Case-Based Reasoning Framework for Conceptual Design of Commercial Buildings. In Proceedings of the 2011 AAAI Spring Symposium Series, Stanford, CA, USA, 21–23 March 2011.
123. Coupry, C.; Noblecourt, S.; Richard, P.; Baudry, D.; Bigaud, D. BIM-Based Digital Twin and XR Devices to Improve Maintenance Procedures in Smart Buildings: A Literature Review. *Appl. Sci.* **2021**, *11*, 6810. [CrossRef]
124. Napps, D.; Pawlowski, D.; König, M. BIM-Based Variant Retrieval of Building Designs Using Case-Based Reasoning and Pattern Matching. In Proceedings of the ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction, Online, 2–4 November 2021; Volume 38, pp. 435–442.
125. Zabin, A.; González, V.A.; Zou, Y.; Amor, R. Applications of Machine Learning to BIM: A Systematic Literature Review. *Adv. Eng. Inform.* **2022**, *51*, 101474. [CrossRef]
126. Zhang, F.; Chan, A.P.C.; Darko, A.; Chen, Z.; Li, D. Integrated Applications of Building Information Modeling and Artificial Intelligence Techniques in the AEC/FM Industry. *Autom. Constr.* **2022**, *139*, 104289. [CrossRef]
127. Lee, P.-C.; Lo, T.-P.; Tian, M.-Y.; Long, D. An Efficient Design Support System Based on Automatic Rule Checking and Case-Based Reasoning. *KSCE J. Civ Eng.* **2019**, *23*, 1952–1962. [CrossRef]
128. Li, P.; Chen, H. Evaluation of Green Building Suppliers Based on IVPLTS-CBR Decision-Making Method. *IJICC* **2022**, *15*, 17–40. [CrossRef]
129. Motawa, I.; Almarshad, A. Case-Based Reasoning and BIM Systems for Asset Management. *Built Environ. Proj. Asset Manag.* **2015**, *5*, 233–247. [CrossRef]
130. Wang, H.; Meng, X.; Zhu, X. Improving Knowledge Capture and Retrieval in the BIM Environment: Combining Case-Based Reasoning and Natural Language Processing. *Autom. Constr.* **2022**, *139*, 104317. [CrossRef]
131. Lee, S.S.; Kim, K.T.; Tanoli, W.A.; Seo, J.W. Flexible 3D Model Partitioning System for ND-Based BIM Implementation of Alignment-Based Civil Infrastructure. *J. Manag. Eng.* **2020**, *36*, 04019037. [CrossRef]
132. Montiel-Santiago, F.J.; Hermoso-Orzáez, M.J.; Terrados-Cepeda, J. Sustainability and Energy Efficiency: BIM 6D. Study of the BIM Methodology Applied to Hospital Buildings. Value of Interior Lighting and Daylight in Energy Simulation. *Sustainability* **2020**, *12*, 5731. [CrossRef]
133. Zhao, H.; Li, X.; Qi, Y. Research on the Application of BIM Technology in the Design of Green Buildings. In Proceedings of the 2021 International Conference on E-Commerce and E-Management (ICECEM), Dalian, China, 24–26 September 2021; IEEE: Piscataway, NJ, USA, 2021; pp. 94–98.
134. Zhou, X.; Wang, J.; Guo, M.; Gao, Z. Cross-Platform Online Visualization System for Open BIM Based on WebGL. *Multimed. Tools Appl.* **2019**, *78*, 28575–28590. [CrossRef]

135. Johansson, M.; Roupé, M.; Bosch-Sijtsema, P. Real-Time Visualization of Building Information Models (BIM). *Autom. Constr.* **2015**, *54*, 69–82. [CrossRef]
136. Boton, C.; Kubicki, S.; Halin, G. The Challenge of Level of Development in 4D/BIM Simulation Across AEC Project Lifecyle. A Case Study. *Procedia Eng.* **2015**, *123*, 59–67. [CrossRef]
137. Zhou, X.; Zhao, J.; Wang, J.; Su, D.; Zhang, H.; Guo, M.; Guo, M.; Li, Z. OutDet: An Algorithm for Extracting the Outer Surfaces of Building Information Models for Integration with Geographic Information Systems. *Int. J. Geogr. Inf. Sci.* **2019**, *33*, 1444–1470. [CrossRef]
138. Xu, Z.; Zhang, L.; Li, H.; Lin, Y.-H.; Yin, S. Combining IFC and 3D Tiles to Create 3D Visualization for Building Information Modeling. *Autom. Constr.* **2020**, *109*, 102995. [CrossRef]
139. Ayman, H.M.; Mahfouz, S.Y.; Alhady, A. Integrated EDM and 4D BIM-Based Decision Support System for Construction Projects Control. *Buildings* **2022**, *12*, 315. [CrossRef]
140. Charlesraj, V.P.C.; Dinesh, T. Status of 4D BIM Implementation in Indian Construction. In Proceedings of the 37th International Symposium on Automation and Robotics in Construction, Online. 27–28 October 2020; pp. 199–206.
141. Jupp, J. 4D BIM for Environmental Planning and Management. *Procedia Eng.* **2017**, *180*, 190–201. [CrossRef]
142. Ding, L.; Zhou, Y.; Akinci, B. Building Information Modeling (BIM) Application Framework: The Process of Expanding from 3D to Computable ND. *Autom. Constr.* **2014**, *46*, 82–93. [CrossRef]
143. Ivson, P.; Nascimento, D.; Celes, W.; Barbosa, S.D. CasCADe: A Novel 4D Visualization System for Virtual Construction Planning. *IEEE Trans. Visual. Comput. Graph.* **2018**, *24*, 687–697. [CrossRef] [PubMed]
144. Park, S.-H.; Kim, E. Middleware for Translating Urban GIS Information for Building a Design Society Via General BIM Tools. *J. Asian Archit. Build. Eng.* **2016**, *15*, 447–454. [CrossRef]
145. Wang, H.; Pan, Y.; Luo, X. Integration of BIM and GIS in Sustainable Built Environment: A Review and Bibliometric Analysis. *Autom. Constr.* **2019**, *103*, 41–52. [CrossRef]
146. Deng, Y.; Cheng, J.C.P.; Anumba, C. Mapping between BIM and 3D GIS in Different Levels of Detail Using Schema Mediation and Instance Comparison. *Autom. Constr.* **2016**, *67*, 1–21. [CrossRef]
147. Hor, A.-H.; Jadidi, A.; Sohn, G. BIM-GIS Integrated Geospatial Information Model Using Semantic Web and RDF Graphs. *ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci.* **2016**, *III–4*, 73–79. [CrossRef]
148. Suwardhi, D.; Trisyanti, S.W.; Ainiyah, N.; Fajri, M.N.; Hanan, H.; Virtriana, R.; Edmarani, A.A. 3D Surveying, Modeling and Geo-Information System of the Newcampus of Itb-Indonesia. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* **2016**, *XLII-2/W2*, 97–105. [CrossRef]
149. Musliman, I.A.; Abdul-Rahman, A.; Coors, V. Incorporating 3D Spatial Operator with Building Information Models in Construction Management Using Geo-DBMS. In Proceedings of the 5th International 3D GeoInfo Conference, Berlin, Germany, 3–4 November 2010.
150. Dore, C.; Murphy, M. Integration of Historic Building Information Modeling (HBIM) and 3D GIS for Recording and Managing Cultural Heritage Sites. In Proceedings of the 2012 18th International Conference on Virtual Systems and Multimedia, Milan, Italy, 2–5 September 2012; IEEE: Piscataway, NJ, USA, 2012; pp. 369–376.
151. Nappo, N.; Mavrouli, O.; Nex, F.; van Westen, C.; Gambillara, R.; Michetti, A.M. Use of UAV-Based Photogrammetry Products for Semi-Automatic Detection and Classification of Asphalt Road Damage in Landslide-Affected Areas. *Eng. Geol.* **2021**, *294*, 106363. [CrossRef]
152. Döllner, J.; Hagedorn, B. Integrating Urban GIS, CAD, and BIM Data by Service-Based Virtual 3D City Models. In *Urban and Regional Data Management*; CRC Press: Boca Raton, FL, USA, 2007; pp. 169–182.
153. Lotai, P.S.; Trivedi, J. Site Layout Planning Through BIM Visualisation—A Case Study. In Proceedings of the 27th Annual Conference of the International Group for Lean Construction, Dublin, Ireland, 3–5 July 2019; pp. 865–876.
154. Zhu, J.; Wu, P. BIM/GIS Data Integration from the Perspective of Information Flow. *Autom. Constr.* **2022**, *136*, 104166. [CrossRef]
155. Vacca, G.; Quaquero, E. BIM-3D GIS: An Integrated System for the Knowledge Process of the Buildings. *J. Spat. Sci.* **2020**, *65*, 193–208. [CrossRef]
156. Xia, H.; Liu, Z.; Efremochkina, M.; Liu, X.; Lin, C. Study on City Digital Twin Technologies for Sustainable Smart City Design: A Review and Bibliometric Analysis of Geographic Information System and Building Information Modeling Integration. *Sustain. Cities Soc.* **2022**, *84*, 104009. [CrossRef]
157. Zhu, J.; Wu, P. Towards Effective BIM/GIS Data Integration for Smart City by Integrating Computer Graphics Technique. *Remote Sens.* **2021**, *13*, 1889. [CrossRef]
158. Wu, Z.; Chen, C.; Cai, Y.; Lu, C.; Wang, H.; Yu, T. BIM-Based Visualization Research in the Construction Industry: A Network Analysis. *Int. J. Environ. Res. Public Health* **2019**, *16*, 3473. [CrossRef] [PubMed]
159. Chen, K.; Chen, W.; Cheng, J.C.P.; Wang, Q. Developing Efficient Mechanisms for BIM-to-AR/VR Data Transfer. *J. Comput. Civ. Eng.* **2020**, *34*, 04020037. [CrossRef]
160. Garbett, J.; Hartley, T.; Heesom, D. A Multi-User Collaborative BIM-AR System to Support Design and Construction. *Autom. Constr.* **2021**, *122*, 103487. [CrossRef]
161. Schiavi, B.; Havard, V.; Beddiar, K.; Baudry, D. BIM Data Flow Architecture with AR/VR Technologies: Use Cases in Architecture, Engineering and Construction. *Autom. Constr.* **2022**, *134*, 104054. [CrossRef]
162. He, Z.; Weng, W. A Risk Assessment Method for Multi-Hazard Coupling Disasters. *Risk Anal.* **2021**, *41*, 1362–1375. [CrossRef]

163. Roopnarine, C.; Ramlal, B.; Roopnarine, R. A Comparative Analysis of Weighting Methods in Geospatial Flood Risk Assessment: A Trinidad Case Study. *Land* **2022**, *11*, 1649. [CrossRef]
164. Sinčić, M.; Bernat Gazibara, S.; Krkač, M.; Lukačić, H.; Mihalić Arbanas, S. The Use of High-Resolution Remote Sensing Data in Preparation of Input Data for Large-Scale Landslide Hazard Assessments. *Land* **2022**, *11*, 1360. [CrossRef]
165. Sugianto, S.; Deli, A.; Miswar, E.; Rusdi, M.; Irham, M. The Effect of Land Use and Land Cover Changes on Flood Occurrence in Teunom Watershed, Aceh Jaya. *Land* **2022**, *11*, 1271. [CrossRef]
166. Cui, P.; Peng, J.; Shi, P.; Tang, H.; Ouyang, C.; Zou, Q.; Liu, L.; Li, C.; Lei, Y. Scientific Challenges of Research on Natural Hazards and Disaster Risk. *Geogr. Sustain.* **2021**, *2*, 216–223. [CrossRef]
167. Wang, J.; Wang, Z.; Cheng, H.; Kang, J.; Liu, X. Land Cover Changing Pattern in Pre- and Post-Earthquake Affected Area from Remote Sensing Data: A Case of Lushan County, Sichuan Province. *Land* **2022**, *11*, 1205. [CrossRef]
168. Wang, Q.; Xie, J.; Yang, J.; Liu, P.; Chang, D.; Xu, W. A Research on Cohesion Hyperspectral Detection Model of Fine-Grained Sediments in Beichuan Debris Flow, Sichuan Province, China. *Land* **2022**, *11*, 1609. [CrossRef]
169. Wu, T.; Xie, X.; Wu, H.; Zeng, H.; Zhu, X. A Quantitative Analysis Method of Regional Rainfall-Induced Landslide Deformation Response Variation Based on a Time-Domain Correlation Model. *Land* **2022**, *11*, 703. [CrossRef]
170. Xu, C.; Fu, H.; Yang, J.; Wang, L. Assessment of the Relationship between Land Use and Flood Risk Based on a Coupled Hydrological–Hydraulic Model: A Case Study of Zhaojue River Basin in Southwestern China. *Land* **2022**, *11*, 1182. [CrossRef]
171. Anil, E.B.; Akinci, B.; Kurc, O.; Garrett, J.H. Building-Information-Modeling–Based Earthquake Damage Assessment for Reinforced Concrete Walls. *J. Comput. Civ. Eng.* **2016**, *30*, 04015076. [CrossRef]
172. Welch, D.P.; Sullivan, T.J.; Filiatrault, A. Potential of Building Information Modelling for Seismic Risk Mitigation in Buildings. *BNZSEE* **2014**, *47*, 253–263. [CrossRef]
173. Vitiello, U.; Ciotta, V.; Salzano, A.; Asprone, D.; Manfredi, G.; Cosenza, E. BIM-Based Approach for the Cost-Optimization of Seismic Retrofit Strategies on Existing Buildings. *Autom. Constr.* **2019**, *98*, 90–101. [CrossRef]
174. Perrone, D.; Filiatrault, A. Automated Seismic Design of Non-Structural Elements with Building Information Modelling. *Autom. Constr.* **2017**, *84*, 166–175. [CrossRef]
175. Chang, Z.; Zhiwen, C.; Meng, W.; Jun, H. 3D Monitoring of Landslide Geological Disaster and Its Application Based on BIM. *J. Chengdu Univ. Technol.* **2017**, *44*, 377–384.
176. Fitz, T.; Theiler, M.; Smarsly, K. A Metamodel for Cyber-Physical Systems. *Adv. Eng. Inform.* **2019**, *41*, 100930. [CrossRef]
177. Lei, Y.; Rao, Y.; Wu, J.; Lin, C.-H. BIM Based Cyber-Physical Systems for Intelligent Disaster Prevention. *J. Ind. Inf. Integr.* **2020**, *20*, 100171. [CrossRef]
178. Wu, W.; Li, W.; Law, D.; Na, W. Improving Data Center Energy Efficiency Using a Cyber-Physical Systems Approach: Integration of Building Information Modeling and Wireless Sensor Networks. *Procedia Eng.* **2015**, *118*, 1266–1273. [CrossRef]
179. Zhang, B.; Yang, B.; Wang, C.; Wang, Z.; Liu, B.; Fang, T. Computer Vision-Based Construction Process Sensing for Cyber–Physical Systems: A Review. *Sensors* **2021**, *21*, 5468. [CrossRef] [PubMed]
180. Lyu, H.-M.; Wang, G.-F.; Shen, J.; Lu, L.-H.; Wang, G.-Q. Analysis and GIS Mapping of Flooding Hazards on 10 May 2016, Guangzhou, China. *Water* **2016**, *8*, 447. [CrossRef]
181. Amirebrahimi, S.; Rajabifard, A.; Mendis, P.; Ngo, T. A Framework for a Microscale Flood Damage Assessment and Visualization for a Building Using BIM–GIS Integration. *Int. J. Digit. Earth* **2016**, *9*, 363–386. [CrossRef]
182. Amirebrahimi, S.; Rajabifard, A.; Mendis, P.; Ngo, T. A BIM-GIS Integration Method in Support of the Assessment and 3D Visualisation of Flood Damage to a Building. *J. Spat. Sci.* **2016**, *61*, 317–350. [CrossRef]
183. Chen, X.-S.; Liu, C.-C.; Wu, I.-C. A BIM-Based Visualization and Warning System for Fire Rescue. *Adv. Eng. Inform.* **2018**, *37*, 42–53. [CrossRef]
184. Cheng, M.-Y.; Chiu, K.-C.; Hsieh, Y.-M.; Yang, I.-T.; Chou, J.-S. Development of BIM-Based Real-Time Evacuation and Rescue System for Complex Buildings. In Proceedings of the ISARC, International Symposium on Automation and Robotics in Construction, Auburn, AL, USA, 18–21 July 2016; Volume 33, p. 1.
185. Gao, X.; Pishdad-Bozorgi, P. Past, Present, and Future of BIM-Enabled Facilities Operation and Maintenance. In Proceedings of the Construction Research Congress 2018, New Orleans, LA, USA, 2–4 April 2018; American Society of Civil Engineers: New Orleans, LA, USA, 2018; pp. 51–61.
186. Wehbe, R.; Shahrour, I. A BIM-Based Smart System for Fire Evacuation. *Future Internet* **2021**, *13*, 221. [CrossRef]
187. Aly, A.M.; Bitsuamlak, G. Aerodynamics of Ground-Mounted Solar Panels: Test Model Scale Effects. *J. Wind Eng. Ind. Aerodyn.* **2013**, *123*, 250–260. [CrossRef]
188. Delavar, M.; Bitsuamlak, G.T.; Dickinson, J.K.; Costa, L.M.F. Automated BIM-Based Process for Wind Engineering Design Collaboration. *Build. Simul.* **2020**, *13*, 457–474. [CrossRef]
189. Reina, G.P.; De Stefano, G. Computational Evaluation of Wind Loads on Sun-Tracking Ground-Mounted Photovoltaic Panel Arrays. *J. Wind Eng. Ind. Aerodyn.* **2017**, *170*, 283–293. [CrossRef]
190. Bre, F.; Gimenez, J.M. A Cloud-Based Platform to Predict Wind Pressure Coefficients on Buildings. *Build. Simul.* **2022**, *15*, 1507–1525. [CrossRef] [PubMed]
191. Hamidavi, T.; Abrishami, S.; Hosseini, M.R. Towards Intelligent Structural Design of Buildings: A BIM-Based Solution. *J. Build. Eng.* **2020**, *32*, 101685. [CrossRef]

192. Cheng, J.C.P.; Kwok, H.H.L.; Li, A.T.Y.; Tong, J.C.K.; Lau, A.K.H. Sensitivity Analysis of Influence Factors on Multi-Zone Indoor Airflow CFD Simulation. *Sci. Total Environ.* **2021**, *761*, 143298. [CrossRef]
193. Usman, F.; Bakar, A.R.A. Thermal Comfort Study Using CFD Analysis in Residential House with Mechanical Ventilation System. In *Proceedings of AICCE'19*; Mohamed Nazri, F., Ed.; Lecture Notes in Civil Engineering; Springer International Publishing: Cham, Switzerland, 2020; Volume 53, pp. 1613–1628. ISBN 978-3-030-32815-3.
194. Xu, F.; Yang, J.; Zhu, X. A Comparative Study on the Difference of CFD Simulations Based on a Simplified Geometry and a More Refined BIM Based Geometry. *AIP Adv.* **2020**, *10*, 125318. [CrossRef]
195. Yan, J.; Kensek, K.; Konis, K.; Noble, D. CFD Visualization in a Virtual Reality Environment Using Building Information Modeling Tools. *Buildings* **2020**, *10*, 229. [CrossRef]
196. Çöltekin, A.; Lochhead, I.; Madden, M.; Christophe, S.; Devaux, A.; Pettit, C.; Lock, O.; Shukla, S.; Herman, L.; Stachoň, Z.; et al. Extended Reality in Spatial Sciences: A Review of Research Challenges and Future Directions. *Int. J. Geo-Inf.* **2020**, *9*, 439. [CrossRef]
197. Hosokawa, M.; Fukuda, T.; Yabuki, N.; Michikawa, T.; Motamedi, A. Integrating CFD and VR for Indoor Thermal Environment Design Feedback. In Proceedings of the 21st International Conference on Computer-Aided Architectural Design Research in Asia (CAADRIA 2016), Melbourne, Australia, 30 March–2 April 2016; pp. 663–672.
198. Azis, S.S.A. Improving Present-Day Energy Savings among Green Building Sector in Malaysia Using Benefit Transfer Approach: Cooling and Lighting Loads. *Renew. Sustain. Energy Rev.* **2021**, *137*, 110570. [CrossRef]
199. Natephra, W.; Motamedi, A.; Yabuki, N.; Fukuda, T. Integrating 4D Thermal Information with BIM for Building Envelope Thermal Performance Analysis and Thermal Comfort Evaluation in Naturally Ventilated Environments. *Build. Environ.* **2017**, *124*, 194–208. [CrossRef]
200. Wang, D.; Meng, J.; Zhang, T. Evaluating the Thermal Performance Index for Future Architectures in China's Hot Summer and Cool Winter Regions. *Sustain. Energy Technol. Assess.* **2021**, *46*, 101241. [CrossRef]
201. Kim, J.B.; Jeong, W.; Clayton, M.J.; Haberl, J.S.; Yan, W. Developing a Physical BIM Library for Building Thermal Energy Simulation. *Autom. Constr.* **2015**, *50*, 16–28. [CrossRef]
202. Chen, Z.; Hammad, A.; Kamardeen, I.; Akbarnezhad, A. Optimising Embodied Energy and Thermal Performance of Thermal Insulation in Building Envelopes via an Automated Building Information Modelling (BIM) Tool. *Buildings* **2020**, *10*, 218. [CrossRef]
203. Ounis, S.; Aste, N.; Butera, F.M.; Pero, C.D.; Leonforte, F.; Adhikari, R.S. Optimal Balance between Heating, Cooling and Environmental Impacts: A Method for Appropriate Assessment of Building Envelope's U-Value. *Energies* **2022**, *15*, 3570. [CrossRef]
204. Seghier, T.E.; Lim, Y.-W.; Harun, M.F.; Ahmad, M.H.; Samah, A.A.; Majid, H.A. BIM-Based Retrofit Method (RBIM) for Building Envelope Thermal Performance Optimization. *Energy Build.* **2022**, *256*, 111693. [CrossRef]
205. Iddon, C.R.; Firth, S.K. Embodied and Operational Energy for New-Build Housing: A Case Study of Construction Methods in the UK. *Energy Build.* **2013**, *67*, 479–488. [CrossRef]
206. Gbadamosi, A.-Q.; Mahamadu, A.-M.; Oyedele, L.O.; Akinade, O.O.; Manu, P.; Mahdjoubi, L.; Aigbavboa, C. Offsite Construction: Developing a BIM-Based Optimizer for Assembly. *J. Clean. Prod.* **2019**, *215*, 1180–1190. [CrossRef]
207. Jalaei, F.; Jrade, A. An Automated BIM Model to Conceptually Design, Analyze, Simulate, and Assess Sustainable Building Projects. *J. Constr. Eng.* **2014**, *2014*, 672896. [CrossRef]
208. Iversen, A.; Roy, N.; Hvass, M.; Jørgensen, M.; Christoffersen, J.; Osterhaus, W.; Johnsen, K. *Daylight Calculations in Practice: An Investigation of the Ability of Nine Daylight Simulation Programs to Calculate the Daylight Factor in Five Typical Rooms*; Danish Building Research Institute, Aalborg University: Copenhagen, Denmark, 2013.
209. Jakica, N. State-of-the-Art Review of Solar Design Tools and Methods for Assessing Daylighting and Solar Potential for Building-Integrated Photovoltaics. *Renew. Sustain. Energy Rev.* **2018**, *81*, 1296–1328. [CrossRef]
210. Schregle, R.; Grobe, L.; Wittkopf, S. Progressive Photon Mapping for Daylight Redirecting Components. *Sol. Energy* **2015**, *114*, 327–336. [CrossRef]
211. Mazzoli, C.; Iannantuono, M.; Giannakopoulos, V.; Fotopoulou, A.; Ferrante, A.; Garagnani, S. Building Information Modeling as an Effective Process for the Sustainable Re-Shaping of the Built Environment. *Sustainability* **2021**, *13*, 4658. [CrossRef]
212. Ruggiero, S.; Iannantuono, M.; Fotopoulou, A.; Papadaki, D.; Assimakopoulos, M.N.; De Masi, R.F.; Vanoli, G.P.; Ferrante, A. Multi-Objective Optimization for Cooling and Interior Natural Lighting in Buildings for Sustainable Renovation. *Sustainability* **2022**, *14*, 8001. [CrossRef]
213. Amoruso, F.M.; Dietrich, U.; Schuetze, T. Integrated BIM-Parametric Workflow-Based Analysis of Daylight Improvement for Sustainable Renovation of an Exemplary Apartment in Seoul, Korea. *Sustainability* **2019**, *11*, 2699. [CrossRef]
214. Zima, K. Impact of Information Included in the BIM on Preparation of Bill of Quantities. *Procedia Eng.* **2017**, *208*, 203–210. [CrossRef]
215. Ying, T.Y.; Mustafa Kamal, E. The Revolution of Quantity Surveying Profession in Building Information Modelling (BIM) Era: The Malaysian Perspective. *IJSCET* **2021**, *12*, 185–195. [CrossRef]
216. Zainon, N.; Mohd-Rahim, F.A.; Salleh, H. The Rise of BIM in Malaysia And Its Impact Towards Quantity Surveying Practices. *MATEC Web Conf.* **2016**, *66*, 00060. [CrossRef]
217. Chen, B.; Jiang, S.; Qi, L.; Su, Y.; Mao, Y.; Wang, M.; Cha, H.S. Design and Implementation of Quantity Calculation Method Based on BIM Data. *Sustainability* **2022**, *14*, 7797. [CrossRef]

218. Ismail, N.A.A.; Adnan, H.; Bakhary, N.A. Building Information Modelling (BIM) Adoption by Quantity Surveyors: A Preliminary Survey from Malaysia. *IOP Conf. Ser. Earth Environ. Sci.* **2019**, *267*, 052041. [CrossRef]
219. Kehily, D.; Underwood, J. Embedding Life Cycle Costing in 5D BIM. *J. Inf. Technol. Constr.* **2017**, *22*, 145–167.
220. Khosakitchalert, C.; Yabuki, N.; Fukuda, T. Improving the Accuracy of BIM-Based Quantity Takeoff for Compound Elements. *Autom. Constr.* **2019**, *106*, 102891. [CrossRef]
221. Khosakitchalert, C.; Yabuki, N.; Fukuda, T. Automated Modification of Compound Elements for Accurate BIM-Based Quantity Takeoff. *Autom. Constr.* **2020**, *113*, 103142. [CrossRef]
222. Khosakitchalert, C.; Yabuki, N.; Fukuda, T. Development of BIM-Based Quantity Takeoff for Light-Gauge Steel Wall Framing Systems. *ITcon* **2020**, *25*, 522–544. [CrossRef]
223. Wong, P.F.; Salleh, H.; Rahim, F.A.M. A Relationship Framework for Building Information Modeling (BIM) Capability in Quantity Surveying Practice and Project Performance. *Inf. Constr.* **2015**, *67*, e119. [CrossRef]
224. Zhan, Z.; Tang, Y.; Wang, C.; Yap, J.B.H.; Lim, Y.S. System Dynamics Outlook on BIM and LEAN Interaction in Construction Quantity Surveying. *Iran J. Sci Technol Trans. Civ. Eng.* **2022**, *46*, 3947–3962. [CrossRef]
225. Mo, L. Research on Application of BIM Technology in Construction Project Cost Management. In Proceedings of the 2018 3rd International Conference on Smart City and Systems Engineering (ICSCSE), Xiamen, China, 29–30 December 2018; IEEE: Piscataway, NJ, USA, 2018; pp. 208–210.
226. Kim, S.; Chin, S.; Kwon, S. A Discrepancy Analysis of BIM-Based Quantity Take-Off for Building Interior Components. *J. Manag. Eng.* **2019**, *35*, 05019001. [CrossRef]
227. Gan, V.J.L.; Luo, H.; Tan, Y.; Deng, M.; Kwok, H.L. BIM and Data-Driven Predictive Analysis of Optimum Thermal Comfort for Indoor Environment. *Sensors* **2021**, *21*, 4401. [CrossRef]
228. Alshehri, F.; Kenny, P.; O'Donnell, J. Requirements for BIM-Based Thermal Comfort Analysis. In Proceedings of the SimAUD 2017: Symposium on Simulation for Architecture and Urban Design, Toronto, ON, Canada, 22–24 May 2017; ACM: New York, NY, USA, 2017; Volume 49, pp. 9–16.
229. Fazeli, A.; Dashti, M.S.; Jalaei, F.; Khanzadi, M. An Integrated BIM-Based Approach for Cost Estimation in Construction Projects. *ECAM* **2021**, *28*, 2828–2854. [CrossRef]
230. Tahir, M.M.; Haron, N.A.; Alias, A.H.; Al-Jumaa, A.T.; Muhammad, I.B.; Harun, A.N. Applications of Building Information Model (BIM) in Malaysian Construction Industry. *IOP Conf. Ser. Mater. Sci. Eng.* **2017**, *291*, 012009. [CrossRef]
231. Chahrour, R.; Hafeez, M.A.; Ahmad, A.M.; Sulieman, H.I.; Dawood, H.; Rodriguez-Trejo, S.; Kassem, M.; Naji, K.K.; Dawood, N. Cost-Benefit Analysis of BIM-Enabled Design Clash Detection and Resolution. *Constr. Manag. Econ.* **2021**, *39*, 55–72. [CrossRef]
232. Lin, W.Y.; Huang, Y.-H. Filtering of Irrelevant Clashes Detected by BIM Software Using a Hybrid Method of Rule-Based Reasoning and Supervised Machine Learning. *Appl. Sci.* **2019**, *9*, 5324. [CrossRef]
233. Hu, Y.; Castro-Lacouture, D.; Eastman, C.M. Holistic Clash Detection Improvement Using a Component Dependent Network in BIM Projects. *Autom. Constr.* **2019**, *105*, 102832. [CrossRef]
234. Akponeware, A.; Adamu, Z. Clash Detection or Clash Avoidance? An Investigation into Coordination Problems in 3D BIM. *Buildings* **2017**, *7*, 75. [CrossRef]
235. Hasannejad, A.; Sardrud, J.M.; Shirzadi Javid, A.A. BIM-Based Clash Detection Improvement Automatically. *Int. J. Constr. Manag.* **2022**, *22*, 1–7. [CrossRef]
236. Pärn, E.A.; Edwards, D.J.; Sing, M.C.P. Origins and Probabilities of MEP and Structural Design Clashes within a Federated BIM Model. *Autom. Constr.* **2018**, *85*, 209–219. [CrossRef]
237. Huang, Y.; Lin, W. Automatic Classification of Design Conflicts Using Rulebased Reasoning and Machine Learning-An Example of Structural Clashes Against the MEP Model. In Proceedings of the ISARC, International Symposium on Automation and Robotics in Construction, Banff, AB, Canada, 21–24 May 2019; Volume 36, pp. 324–331.
238. Zhao, X.; Tan, Y.; Shen, L.; Zhang, G.; Wang, J. Case-Based Reasoning Approach for Supporting Building Green Retrofit Decisions. *Build. Environ.* **2019**, *160*, 106210. [CrossRef]
239. Abdelaal, F.; Guo, B.H.W. Stakeholders' Perspectives on BIM and LCA for Green Buildings. *J. Build. Eng.* **2022**, *48*, 103931. [CrossRef]
240. Malacarne, G.; Marcher, C.; Riedl, M.; Matt, D. Investigating Benefits and Criticisms of Bim for Construction Scheduling in SMEs: An Italian Case Study. *Int. J. Sustain. Dev. Plan.* **2018**, *13*, 139–150. [CrossRef]
241. Solla, M.; Ismail, L.H.; Yunus, R. Investigation on the Potential of Integrating BIM into Green Building Assessment Tools. *ARPN J. Eng. Appl. Sci.* **2016**, *11*, 2412–2418.
242. Zhang, L.; Chu, Z.; Song, H. Understanding the Relation between BIM Application Behavior and Sustainable Construction: A Case Study in China. *Sustainability* **2019**, *12*, 306. [CrossRef]
243. Gao, H.; Koch, C.; Wu, Y. Building Information Modelling Based Building Energy Modelling: A Review. *Appl. Energy* **2019**, *238*, 320–343. [CrossRef]
244. Farzaneh, A.; Monfet, D.; Forgues, D. Review of Using Building Information Modeling for Building Energy Modeling during the Design Process. *J. Build. Eng.* **2019**, *23*, 127–135. [CrossRef]
245. Wang, J.; Gao, X.; Zhou, X.; Xie, Q. Multi-Scale Information Retrieval for BIM Using Hierarchical Structure Modelling and Natural Language Processing. *ITcon* **2021**, *26*, 409–426. [CrossRef]

246. Xiao, Y.; Yi, S.; Tang, Z. Integrated Flood Hazard Assessment Based on Spatial Ordered Weighted Averaging Method Considering Spatial Heterogeneity of Risk Preference. *Sci. Total Environ.* **2017**, *599–600*, 1034–1046. [CrossRef]
247. Nguyen, H.P.; Le, P.Q.H.; Pham, V.V.; Nguyen, X.P.; Balasubramaniam, D.; Hoang, A.-T. Application of the Internet of Things in 3E (Efficiency, Economy, and Environment) Factor-Based Energy Management as Smart and Sustainable Strategy. *Energy Sources Part A Recovery Util. Environ. Eff.* **2021**, *43*, 1–23. [CrossRef]
248. Rowland, A.; Folmer, E.; Beek, W. Towards Self-Service GIS—Combining the Best of the Semantic Web and Web GIS. *IJGI* **2020**, *9*, 753. [CrossRef]
249. Hussain, Y.; Schlögel, R.; Innocenti, A.; Hamza, O.; Iannucci, R.; Martino, S.; Havenith, H.-B. Review on the Geophysical and UAV-Based Methods Applied to Landslides. *Remote Sens.* **2022**, *14*, 4564. [CrossRef]
250. Cao, D.; Li, H.; Wang, G.; Luo, X.; Tan, D. Relationship Network Structure and Organizational Competitiveness: Evidence from BIM Implementation Practices in the Construction Industry. *J. Manag. Eng.* **2018**, *34*, 04018005. [CrossRef]
251. Gao, X.; Pishdad-Bozorgi, P. BIM-Enabled Facilities Operation and Maintenance: A Review. *Adv. Eng. Inform.* **2019**, *39*, 227–247. [CrossRef]
252. Ardani, J.A.; Utomo, C.; Rahmawati, Y. Model Ownership and Intellectual Property Rights for Collaborative Sustainability on Building Information Modeling. *Buildings* **2021**, *11*, 346. [CrossRef]
253. Baharom, M.H.; Habib, S.N.H.A.; Ismail, S. Building Information Modelling (BIM): Contractual Issues of Intellectual Property Rights (IPR) in Construction Projects. *Int. J. Sustain. Constr. Eng. Technol.* **2021**, *12*, 170–178. [CrossRef]
254. Deng, Y.; Li, J.; Wu, Q.; Pei, S.; Xu, N.; Ni, G. Using Network Theory to Explore BIM Application Barriers for BIM Sustainable Development in China. *Sustainability* **2020**, *12*, 3190. [CrossRef]
255. GhaffarianHoseini, A.; Zhang, T.; Nwadigo, O.; GhaffarianHoseini, A.; Naismith, N.; Tookey, J.; Raahemifar, K. Application of ND BIM Integrated Knowledge-Based Building Management System (BIM-IKBMS) for Inspecting Post-Construction Energy Efficiency. *Renew. Sustain. Energy Rev.* **2017**, *72*, 935–949. [CrossRef]
256. Liu, Z.; Lu, Y.; Shen, M.; Peh, L.C. Transition from Building Information Modeling (BIM) to Integrated Digital Delivery (IDD) in Sustainable Building Management: A Knowledge Discovery Approach Based Review. *J. Clean. Prod.* **2021**, *291*, 125223. [CrossRef]
257. Tallgren, M.V.; Roupé, M.; Johansson, M.; Bosch-Sijtsema, P. BIM Tool Development Enhancing Collaborative Scheduling for Pre-Construction. *ITcon* **2020**, *25*, 374–397. [CrossRef]
258. Adibfar, A.; Costin, A.; Issa, R.R.A. Design Copyright in Architecture, Engineering, and Construction Industry: Review of History, Pitfalls, and Lessons Learned. *J. Leg. Aff. Disput. Resolut. Eng. Constr.* **2020**, *12*, 04520032. [CrossRef]
259. Adibfar, A.; Costin, A.; Issa, R.R. Review of Copyright Challenges in AECO Industry and Prospective Developments for Building Information Modeling (BIM). In Proceedings of the Construction Research Congress 2020, Tempe, AZ, USA, 8–10 March 2020; American Society of Civil Engineers: Tempe, AZ, USA, 2020; pp. 1168–1176.
260. Erpay, M.Y.; Sertyesilisik, B. Preliminary Checklist Proposal for Enhancing BIM-Based Construction Project Contracts. *ITcon* **2021**, *26*, 341–365. [CrossRef]
261. Jo, T.M.; Ishak, S.S.M.; Rashid, Z.Z.A. Overview of the Legal Aspects and Contract Requirements of the BIM Practice in Malaysian Construction Industry. *MATEC Web Conf.* **2018**, *203*, 02011. [CrossRef]
262. Liu, H.; Abudayyeh, O.; Liou, W. BIM-Based Smart Facility Management: A Review of Present Research Status, Challenges, and Future Needs. In Proceedings of the Construction Research Congress 2020: Computer Applications, Tempe, AZ, USA, 8–10 March 2020; American Society of Civil Engineers: Reston, VA, USA, 2020; pp. 1087–1095.
263. Hooper, M. Automated Model Progression Scheduling Using Level of Development. *Constr. Innov.* **2015**, *15*, 428–448. [CrossRef]
264. Andriamamonjy, A.; Saelens, D.; Klein, R. A Combined Scientometric and Conventional Literature Review to Grasp the Entire BIM Knowledge and Its Integration with Energy Simulation. *J. Build. Eng.* **2019**, *22*, 513–527. [CrossRef]
265. Costin, A.; Adibfar, A.; Hu, H.; Chen, S.S. Building Information Modeling (BIM) for Transportation Infrastructure—Literature Review, Applications, Challenges, and Recommendations. *Autom. Constr.* **2018**, *94*, 257–281. [CrossRef]
266. Elnabawi, M.H.; Hamza, N. Investigating Building Information Model (BIM) to Building Energy Simulation (BES): Interoperability and Simulation Results. *IOP Conf. Ser. Earth Environ. Sci.* **2019**, *397*, 012013. [CrossRef]
267. Shirowzhan, S.; Sepasgozar, S.M.E.; Edwards, D.J.; Li, H.; Wang, C. BIM Compatibility and Its Differentiation with Interoperability Challenges as an Innovation Factor. *Autom. Constr.* **2020**, *112*, 103086. [CrossRef]
268. Zhong, B.; Gan, C.; Luo, H.; Xing, X. Ontology-Based Framework for Building Environmental Monitoring and Compliance Checking under BIM Environment. *Build. Environ.* **2018**, *141*, 127–142. [CrossRef]
269. Muller, M.F.; Garbers, A.; Esmanioto, F.; Huber, N.; Loures, E.R.; Canciglieri Junior, O. Data Interoperability Assessment Though IFC for BIM in Structural Design–a Five-Year Gap Analysis. *J. Civ. Eng. Manag.* **2017**, *23*, 943–954. [CrossRef]
270. Steel, J.; Drogemuller, R.; Toth, B. Model Interoperability in Building Information Modelling. *Softw. Syst. Model.* **2012**, *11*, 99–109. [CrossRef]
271. Coraglia, U.M.; Simeone, D.; Cursi, S.; Fioravanti, A.; Wurzer, G.; D'Alessandro, D. A Simulation Model for Logical and Operative Clash Detection. In Proceedings of the 35th eCAADe Conference, Rome, Italy, 20–22 September 2017.
272. Hosny, A.; Nik-Bakht, M.; Moselhi, O. Physical Distancing Analytics for Construction Planning Using 4D BIM. *J. Comput. Civ. Eng.* **2022**, *36*, 04022012. [CrossRef]
273. Tak, A.N.; Taghaddos, H.; Mousaei, A.; Bolourani, A.; Hermann, U. BIM-Based 4D Mobile Crane Simulation and Onsite Operation Management. *Autom. Constr.* **2021**, *128*, 103766. [CrossRef]

274. Hu, Z.-Z.; Leng, S.; Lin, J.-R.; Li, S.-W.; Xiao, Y.-Q. Knowledge Extraction and Discovery Based on BIM: A Critical Review and Future Directions. *Arch. Comput. Methods Eng.* **2022**, *29*, 335–356. [CrossRef]
275. Biel, S. Concept of Using the BIM Technology to Support the Defect Management Process. *Arch. Civ. Eng.* **2021**, *67*, 209–229. [CrossRef]
276. Liu, Z.; Zhang, C.; Guo, Y.; Osmani, M.; Demian, P. A Building Information Modelling (BIM) Based Water Efficiency (BWe) Framework for Sustainable Building Design and Construction Management. *Electronics* **2019**, *8*, 599. [CrossRef]
277. Zaker, R.; Coloma, E. Virtual Reality-Integrated Workflow in BIM-Enabled Projects Collaboration and Design Review: A Case Study. *Vis. Eng.* **2018**, *6*, 1–15. [CrossRef]
278. Jung, J.; Stachniss, C.; Ju, S.; Heo, J. Automated 3D Volumetric Reconstruction of Multiple-Room Building Interiors for as-Built BIM. *Adv. Eng. Inform.* **2018**, *38*, 811–825. [CrossRef]
279. Tang, L.; Li, L.; Ying, S.; Lei, Y. A Full Level-of-Detail Specification for 3D Building Models Combining Indoor and Outdoor Scenes. *Int. J. Geo-Inf.* **2018**, *7*, 419. [CrossRef]
280. Boton, C. Supporting Constructability Analysis Meetings with Immersive Virtual Reality-Based Collaborative BIM 4D Simulation. *Autom. Constr.* **2018**, *96*, 1–15. [CrossRef]
281. Crowther, J.; Ajayi, S.O. Impacts of 4D BIM on Construction Project Performance. *Int. J. Constr. Manag.* **2021**, *21*, 724–737. [CrossRef]
282. Baldrich Aragó, A.; Roig Hernando, J.; Llovera Saez, F.J.; Coll Bertran, J. Quantity Surveying and BIM 5D. Its Implementation and Analysis Based on a Case Study Approach in Spain. *J. Build. Eng.* **2021**, *44*, 103234. [CrossRef]
283. Elghaish, F.; Abrishami, S.; Abu Samra, S.; Gaterell, M.; Hosseini, M.R.; Wise, R. Cash Flow System Development Framework within Integrated Project Delivery (IPD) Using BIM Tools. *Int. J. Constr. Manag.* **2021**, *21*, 555–570. [CrossRef]
284. Daniotti, B.; Pavan, A.; Lupica Spagnolo, S.; Caffi, V.; Pasini, D.; Mirarchi, C. Benefits and Challenges Using BIM for Operation and Maintenance. In *BIM-Based Collaborative Building Process Management*; Springer Tracts in Civil Engineering; Springer International Publishing: Cham, Switzerland, 2020; pp. 167–181. ISBN 978-3-030-32888-7.
285. Georgiadou, M.C. An Overview of Benefits and Challenges of Building Information Modelling (BIM) Adoption in UK Residential Projects. *Constr. Innov.* **2019**, *19*, 298–320. [CrossRef]
286. Central Committee of the Chinese Communist Party; State Council of the People's Republic of China. *Opinions of the Central Committee of the Communist Party of China and the State Council on the Key Efforts to Comprehensively Promote Rural Revitalization in 2022*; State Council of the People's Republic of China: Beijing, China, 2022.