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Research Article

Exploring Key Elements and Performance of BIM and VR Technologies in the Project Management of Assembled Buildings

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The construction industry is the material basis for national economic development. Since the reform and opening up, the construction industry in China has been in a state of continuous expansion to promote economic and social development. However, the traditional mode of building construction in China is rather crude, which not only fails to meet the needs of rapid urban development, but also causes serious environmental pollution and resource shortage. Therefore, it is necessary to conduct relevant technological updates and industrial restructuring to solve these problems, so as to achieve sustainable development. With the advantages of energy saving, low carbon, and short construction cycle, assembled buildings have become a new direction for the transformation of the construction industry. However, China's assembled buildings are still in the promotion stage, and the technical level is relatively backward. Especially in the construction process, there is a lack of management mechanisms adapted to assembled buildings. Hence, some new technologies need to be introduced to promote the development of assembled construction in China. In recent years, with the increasing popularity of assembled construction in China, the technology of assembled construction has also been improving. Also, the interface between assembled construction and modern technology has become more and more obvious. In particular, the application of BIM and VR technologies has been of great help to the development of assembled buildings. To be specific, the combination of these two technologies allows for better control of all aspects of the construction site, thus making the construction project easier to manage. In addition, the application of BIM and VR technologies can not only improve the efficiency of project management, but also improve the quality of construction of assembled buildings, thereby reducing the environmental pollution caused by construction. As a result, the application of BIM and VR technologies has greatly promoted the development of project management of assembled buildings. This paper integrates BIM and VR technologies to study and discuss the key elements and performance of the application of project management for assembled buildings.

1. Introduction

For a long time, China has adopted a relatively rugged economic development mode in order to achieve rapid economic and social development. Under this development mode, the excessive input of resources, energy, and other factors of production has brought about a great number of serious problems, such as high energy consumption, serious overcapacity, and serious environmental pollution [1]. As a result, in recent years, the relevant authorities have proposed to transform the mode of economic development and change the industrial structure. To be specific, the government has advocated the transformation of industries from a sloppy mode to an intensive economic mode in order to promote sustainable and healthy economic development [2]. However, the way of economic development involves many fields and links, and is a long-term task facing China's economic development. In China, the construction industry is a fundamental industry, which accounts for a large proportion of China's gross national product [3]. It can have a significant impact on the development of various industries and the improvement of people's living conditions [4].

However, China's construction industry still adopts a relatively crude development model in terms of design, construction, and other technologies. As a result, although China's construction industry is developing at a relatively rapid pace, there is still a considerable gap compared to that of developed countries. The long-term adoption of traditional construction methods has resulted in serious waste of resources and serious environmental pollution and other problems [5]. What is more, most of the labor force in the traditional construction method is mainly migrant workers with low education level. Nowadays, with the development of modern society, the number of migrant workers is growing slowly [6]. The existing migrant workforce is predominantly older, and this has become a problem for the construction industry in terms of recruitment. Hence, the government proposes to promote the reform and development, transformation, and upgrading of the construction industry, so as to achieve a sustainable development model for the construction industry [7]. Specifically, the sustainable development mode relies on some modern construction technologies, innovative production techniques, and intelligent digital technologies, such as building information modeling [8] and virtual reality [9]. The industrialization of construction has become a hot topic in the construction industry, as it uses an industrial approach to organization and can improve production efficiency and product standardization.

Today, with real estate as the main economic pillar, people have been advocating green buildings and smart cities and pushing for a sustainable development path [10]. As a result, the traditional construction industry must be reformed to meet the corresponding sustainable development requirements. In particular, the construction methods must change from the traditional crude construction methods to centralize the production of the relevant components, thus reducing the environmental pollution caused during construction [11]. At the same time, it is necessary to improve the overall quality of the construction personnel on-site and to increase the amount of advanced machinery and equipment invested in order to improve production efficiency. In order to optimize the way in which buildings are produced and to improve their quality, promoting the industrialization of building production is an effective means of doing so. At the same time, this means can significantly decrease the cost of building production and improve the utilization rate of raw materials for building production, thus reducing the environmental impact of the building production process [12]. Limited by the level of development of China's economy and technology, although the industrialization of construction production was proposed in China a long time ago, the industrialization of construction in China has not been further developed. However, in recent years, with the further advancement of the concept of environmental protection, relevant concepts are being introduced [13]. The implementation of construction industrialization and assembly construction projects will be actively promoted by the state, industry, and local governments. Starting with some classic engineering projects, the localization of assembly technology is steadily moving forward [14]. With the current development, in the future, the hotspots of the real estate industry and the construction industry will also certainly focus on the development of assembly-type construction, and the production units related to it across the country will be scrambling to enter the field of assembly-type construction.

The industrialization of assembled buildings has become a new worldwide direction in the development of the construction industry [15]. Also, it has been an urgent need for the transformation of China's production methods and the construction of new urbanization. In recent years, the relatively high level of interest in assembled buildings, coupled with the preferential measures for assembled buildings introduced by the relevant state departments, has led the construction industry to pay great attention to assembled buildings. Assembled construction is currently in a critical transition phase and is likely to become popular in the future [16]. The entire construction process of an assembled building involves a large number of processes and participants, and is closely linked and complex [17]. The traditional management mode has led to a variety of problems in the construction of assembled buildings, including slow construction, high construction costs, and safety hazards. Failure to consider the subsequent production, processing, and installation of prefabricated components during the design phase can result in a large number of design changes and rework, which can have a negative impact on project quality and construction efficiency [18]. Therefore, it is important to coordinate the relationship between the whole processes of assembled building construction and to carry out research on the management of the whole process of intelligent construction of assembled buildings [19]. In this way, the information can flow smoothly between the various stages and parties involved, in order to solve the above problems and achieve the goal of data integration and information management of the whole process of assembled building construction. The application and promotion of assembled buildings in China are still at an early stage, with many key problems such as backward production facilities and low technology levels. Therefore, the use of BIM, IoT [20], RFID [21], machine learning [22, 23], and VR technologies can help to develop a new construction model for assembled buildings. This will help to improve the overall quality and efficiency of assembled buildings, and to achieve optimal decision-making in the processing and production stages of assembled buildings and the traceability of prefabricated components [24]. Assembled construction means that the building components are delivered to the construction site from the factory in a standardized design and assembled into a whole by means of lifting. The main advantages of assembled buildings are that they are prefabricated, installed, and furnished in an integrated manner, with low work intensity, fast assembly, and environmental protection. In reality, the environmental benefits of assembled buildings are shown in Figure 1. In addition, the wide range of application of the assembled buildings can help to decrease the construction waste significantly [25].

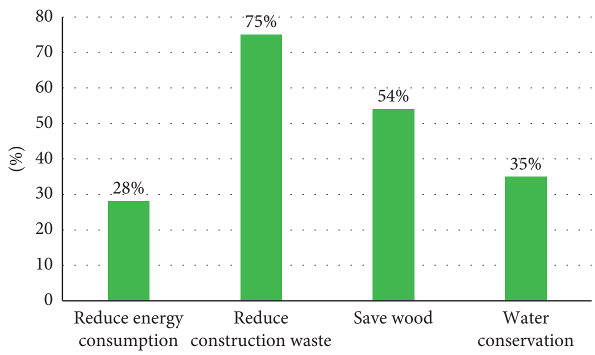

Figure 1: Environmental benefits of assembled buildings.

The assembled building is a modular building design supported by information technology. Unlike traditional construction methods, it is characterized by collaboration, integration, and refinement, as shown in Table 1.

BIM is an integrated data and information model based on three-dimensional digital technology, and a large amount of digital information is a prerequisite for intelligent construction [26]. This technology enables the integration of all building information from the design, production, assembly, and operation and maintenance phases in one information base. The powerful information integration capabilities of BIM technology can provide the basis for all decisions in the building process from design concept to demolition, achieving the building goals of improving quality and efficiency, shortening construction time, reducing costs, and saving resources. The main objective of BIM is to have a powerful 3D virtual model database that provides complete project information [27]. Not only does the model contain the properties of each component, but in addition to this it is possible to add content such as installation locations. As a result, BIM technology effectively improves the integration of construction information and provides a platform for collaboration and data sharing between all parties involved in the construction project. The digital presentation of the geometry and functionality of components by BIM technology can facilitate the assembly of prefabricated components on-site, but only if the BIM model is complete, accurate, and updated in real time [28]. During the construction phase of an assembled building, there are many potential risks due to the large distances involved, the large number of units involved, the outdated production and construction technology, and the inapplicability of the management mechanism. The use of BIM technology allows manufacturers to obtain the design information of prefabricated components directly from the BIM model, ensuring the timeliness and accuracy of the processing information and avoiding errors in the transmission process.

In recent years, VR technology has also started to be used in the construction industry [29]. In recent years, research into VR technology has only just begun in China, and research into the application of this technology in the construction sector has lagged behind. With the continuous development of social economy, virtual reality technology has gradually penetrated into people's life, which can effectively simulate the interaction technology of seeing, hearing, and moving in the natural environment, with three characteristics of immersion, interactivity, and illusion. The combination of BIM and VR technology is based on 3D visualization, simulation, and other information processing and the presentation of virtual reality results [30]. Specifically, the 3D view method is used to obtain the model parameters of an assembled building. The use of VR technology enables a virtual roaming of the production and construction process of an assembled building and provides management and technical guidance to the production and construction staff. In addition, by creating a component enquiry system and a virtual display of the component production and construction process, virtual reality visualization of modern construction can be realized, so that assembly building practitioners can better understand the whole process of assembly building production and construction. As a result, the integration of BIM and VR technology can enhance the realism of the simulation as well as allow for the visualization of building details [31]. In addition, any information can be integrated into the created virtual environment, such as the creation of virtual scenic sites, interactive scene roaming, and the simulation of complex local construction scenarios. The traceability function is also based on BIM and VR technology and allows managers to monitor cost information and construction progress in real time.

Table 1: Comparison between assembled and traditional constructions.

Construction session	Assembled construction	Traditional construction
Design	Information-based collaborative design	Independent design for each department
Construction	Factory production, professional lifting, and fine installation	Manual handling on-site
Management	General contracting management mode	Each participant seeks to maximize their own interests
Decoration	Integrated design and simultaneous installation with the main structure	Secondary decoration

In the context of the rapid development of modern technology, the construction industry in China is paying more and more attention to the collection, analysis, sharing, and cross-application of information data on the whole process of construction projects. Many scholars are in favor of a holistic view based on the whole construction process and the whole industrial chain to promote the technological reform of the modern construction industry and the concept of intelligent construction management. They have fully researched the application of big data computing, physical connectivity, and information technology integration in the whole construction process and all industries involved, and theoretical studies on intelligent construction have also been carried out. Therefore, this study combines BIM and VR technologies and the integrated application of various information technologies to investigate the key elements and performance of project management for assembled buildings, in order to provide ideas and references for the high-quality development of assembled buildings. The technical framework of this paper is shown in Figure 2.

2. BIM Technology

BIM is an integrated data and information model, based on 3D digital technology, and a large amount of digital information is a prerequisite for intelligent construction. The ultimate goal of BIM technology is to enable construction projects to save resources, reduce costs, and thereby reduce environmental pollution at every stage of their life cycle. BIM technology breaks down the fragmentation of the construction industry and connects the information of each stage. In China, the use of BIM technology is of positive significance to the construction of an economical society and the creation of a harmonious society, as well as promoting the sustainable development of cities.

2.1. Principle of BIM Technology in Assembled Buildings. The design method for assembled buildings has been transformed from the design of cast-in-place structures. The common method used to carry out the design is to complete the overall design first and then to split the design to complete the design of the elements and details. However, the design method is mainly designed independently by different design units, which can lead to safety hazards and conflicts with the concept of industrialization of construction. Therefore, a BIM-based approach to assembly building design should begin with the establishment of a BIM collaborative design platform. With the help of this platform, designers can access the design results of other members in a timely manner and facilitate design coordination between different units. After completing the scheme design, a standard prefabricated component library should be built on the platform by the lead designer to reduce the design of components and the variety of components in the design process. The library is also shared between the production and design units to ensure that the designed components are within the capacity of the factory. Once the component library has been created, the designer can extract or add components from it to complete a preliminary design model of the components. In addition, after the construction drawing model is completed, the designer will need to deepen the design of the component model by combining the comprehensive requirements of multiple disciplines. The BIM-based design management structure is shown in Figure 3.

2.2. Analysis of BIM Technology in Assembled Buildings. The traditional assembly building design process and the traditional BIM design process are not suitable for the application of BIM technology in assembly building design. Therefore, in order to utilize BIM technology in the design phase of an assembly building, the design process needs to be rearranged, as shown in Figure 4.

During the design phase, the main task of the design team is to work with the owner to evaluate the feasibility of the assembled building, determine the needs of the assembled building, and initially define the architectural and structural design of the building. The use of BIM technology to create a schematic design model can help the owner to better understand the design. At the same time, this model will also serve as a basis for the subsequent design and as a guiding document. The construction of the BIM model and the production of the components are based on a precast component library, the creation of which is one of the core tasks of the design phase. In the precast component library formation and refinement phase, designers create a precast component library for the project based on the functional and appearance requirements of the building. Subsequently, during the creation of the preliminary design model, the designers can supplement the prefabricated component library according to their specific needs; at the same time, the production unit can ask the designers to adjust the components in the prefabricated component library that are difficult to meet the technical requirements of the factory. In the BIM model construction stage, designers create BIM models of assembled buildings by calling up components from the prefabricated component library on the basis of the schematic design model. In model optimization, BIM tools such as clash checking are used to identify problems in the design and optimize the BIM models of the various disciplines.

In fact, the creation of a prefabricated component library is the focus of the implementation of the BIM-based assembly building design method, which serves the design of the BIM model of the assembly building by providing prefabricated components. In order to play the role of a prefabricated component library, its creation should include both the creation of prefabricated components and the organization and management of the prefabricated component library, as shown in Figure 5.

The components of assembled buildings are not universal between different structural systems, so the classification of prefabricated components should be based on the structural system and established according to the different categories of specialties and structures. After the classification of the components has been completed, standard and universal precast components are selected for storage. In addition, the components to be stored should meet the modal requirements of the assembly design to ensure that the variety of components is within a reasonable range.

3. VR Technology

Virtual reality technology is the simulation of the environment and things that exist in reality, creating a new space of virtual reality through the computer. However, as we all know, the real environment is so complex that it does not only exist in a flat visual effect, but even reaches a three-dimensional dynamic effect, with a unique presence in many aspects such as smell and hearing, so virtual reality technology is the result of a combination of technologies from many disciplines, including human-machine interface technology, sensing technology, simulation technology, and

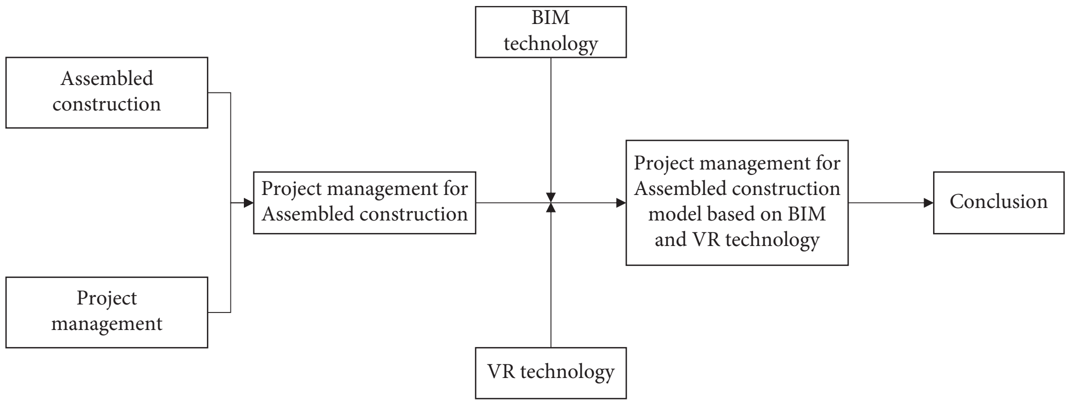

Figure 2: Technical framework of this research.

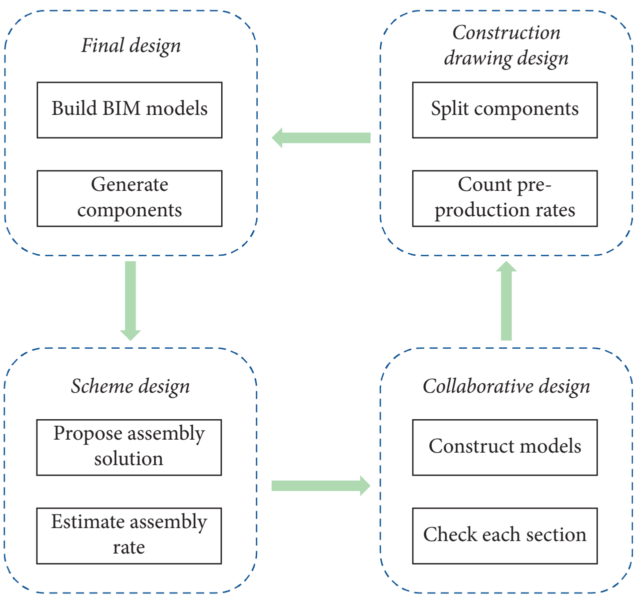

Figure 3: BIM-based design management structure.

network sensing technology. The ideal state of virtual reality is like the creation of an alternative real-life scenario, where the creation of the scenario actually requires the integration of multiple information. VR is a multi-sensory effect created by sensing devices, i.e., a 3D interactive system. VR is also a high-end project at the forefront of science, due to the combined involvement of multiple high-end technologies.

All computer-based software requires a great deal of time and effort to create the model, and this is also the case with virtual construction technology. Digital modeling is the transformation of a building model into a digital signal that can be processed and stored. Digital modeling is fundamental to the realization of virtual construction. In the modern construction industry, the main application of VR technology can be seen in Figure 6.

4. Integration of BIM and VR Technology

4.1. Process of Combining BIM and VR Technology. Before designing the management mode of assembly building construction application based on BIM and VR technology, it is important to first understand the implementation idea of BIM application clearly in the assembly construction project. Based on a full understanding of the project process, the resources are integrated to facilitate the management of information flow during the complex construction process, as detailed in Figure 7.

The combination of BIM and VR technology will enable the construction and development of new projects to be fully promoted on the basis of the original cost control. At the level of the company's project management system, constant exploration and discovery are required to discover new management system mechanisms, thus promoting the reform and innovation of the company's system. For example, as the company continues to develop and grow, its performance increases significantly and sometimes several projects need to be constructed simultaneously. The company can set up a large project department in accordance with the actual situation. In the event of difficulties in the actual construction process, such as a shortage of construction materials or insufficient management staff, each project within a large project department can negotiate its own secondment through the internal system management platform. The cooperation between the various project departments will maximize the utilization of resources.

4.2. Application of BIM and VR Technologies in Construction. Unlike traditional construction management, the component-based approach is at an assembly building construction site. According to the project carried out mainly based on components, the detailed process is shown in Figure 8.

During the construction process, the simulation of the construction progress in the virtual environment allows the problems identified to be dealt with in time for the optimization of the construction plan. At the same time, it provides a technical guarantee that the actual construction can proceed smoothly, ensuring that the construction can be completed within the scheduled time frame while meeting the quality requirements and avoiding unnecessary losses in terms of cost and schedule. The basic elements of cost management during the construction phase of an assembled building include cost budgeting, preparation of cost plans, and cost tracking and control. During the construction

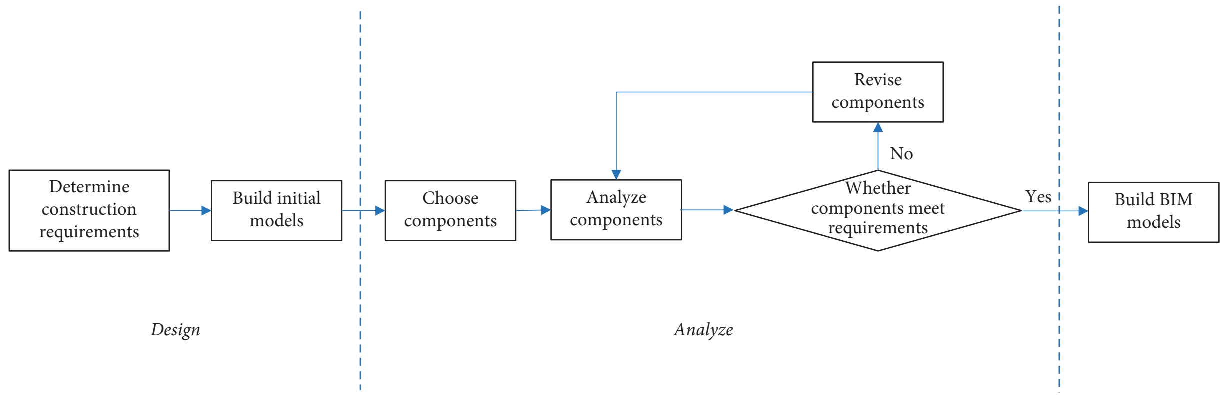

Figure 4: Process of BIM technology application.

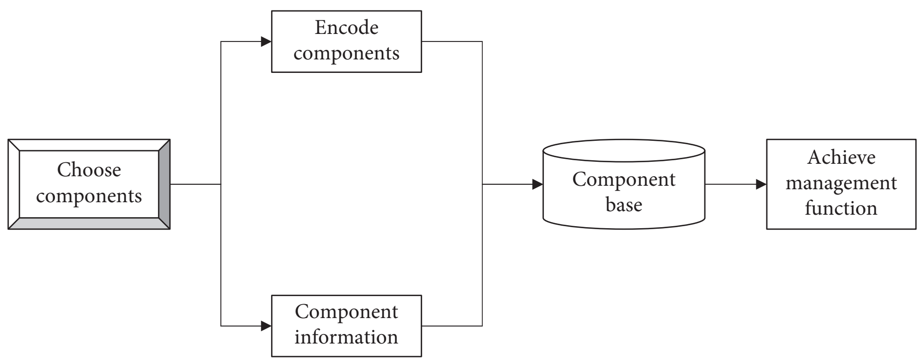

Figure 5: Process of building component base.

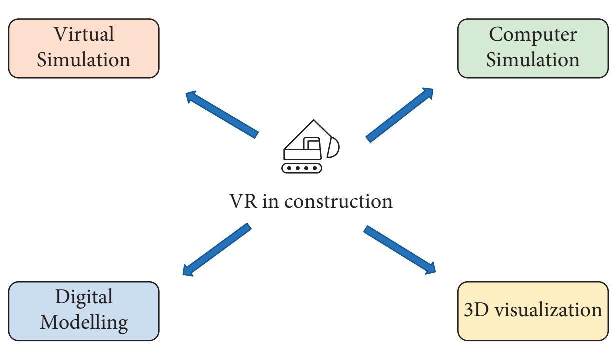

Figure 6: Main application of VR technology.

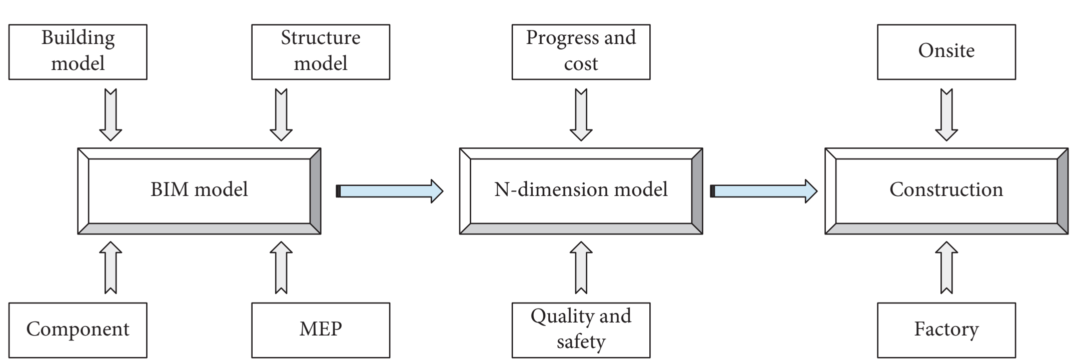

Figure 7: Process of BIM and VR.

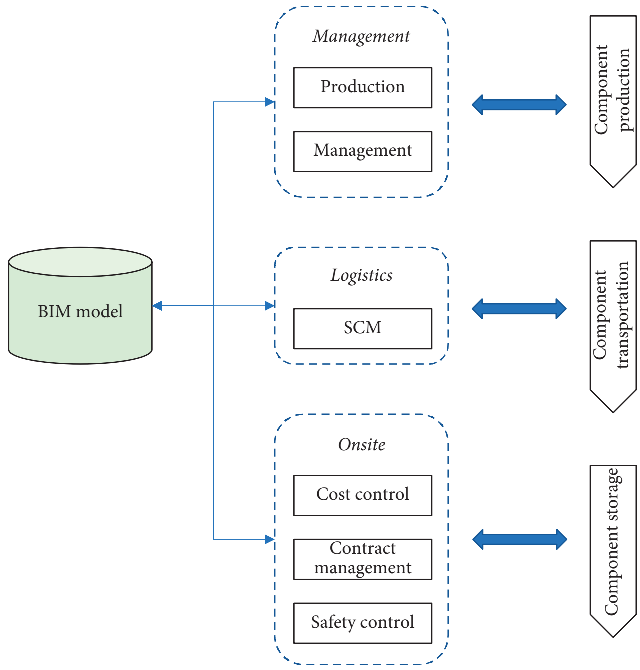

Figure 8: Process of BIM model.

preparation stage, the construction unit calculates the forecast cost of the project based on the quantity calculation, resource plan, and capital plan, and formulates the cost plan for the project. During the execution of the project, the cost plan is used to target and control the factors that affect the construction costs of the assembly building. At the same time, the actual costs of the project are periodically calculated and analyzed for deviations from the planned costs, so that timely measures can be taken to remedy the situation. BIM-based construction cost management can automatically calculate the latest project quantities and assist in costing processes such as cost forecasting, project progress payment, and project settlement.

5. Conclusion

The existing development trend in the construction industry is gradually moving toward industrialization and urbanization. In this context, the overall construction industry development model has changed considerably on the basis of the past. Based on BIM and VR technology, this paper analyzes the characteristics, development process, application status, and some practical problems faced by China's assembled buildings. In addition to this, this study discusses the logic of a standardized design system for assembled buildings that connects and combines modern information technology with the structure of the assembly system. Finally, the application framework and application objectives involved in this system model are analyzed as the main body and classified according to the different stages in order to promote the development of the project construction. Practical solutions to the problems of this technology need to be proposed and implemented into concrete actions. The assembled construction model has become an irresistible trend in the construction industry, and the application of new technologies will certainly bring high efficiency and profitability to the management of assembled construction projects. However, this paper has only studied the application of BIM and VR technology in the design and construction phases of assembly design, but not the application of BIM technology in the production and operation phases of the factory.

Data Availability

The labeled data set used to support the findings of this study is available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

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References

[1] Y. Feng, S. Wang, Y. Sha, Q. Ding, J. Yuan, and X. Guo, "Coal power overcapacity in China: province-Level estimates and policy implications," *Resources, Conservation and Recycling*, vol. 137, pp. 89–100, 2018.
[2] J. Wu and Z. Wang, "Research on the impact of OFDI on China's industrial structure upgrading: based on the analysis of countries along the" belt and road," *Frontiers in Business, Economics and Management*, vol. 3, no. 2, pp. 43–46, 2022.
[3] P. Saieg, E. D. Sotelino, D. Nascimento, and R. G. G. Caiado, "Interactions of building information modeling, lean and sustainability on the architectural, engineering and construction industry: a systematic review," *Journal of Cleaner Production*, vol. 174, pp. 788–806, 2018.
[4] M. Regona, T. Yigitcanlar, B. Xia, and R. Y. M. Li, "Opportunities and adoption challenges of ai in the construction industry: a prisma review," *Journal of Open Innovation: Technology, Market, and Complexity*, vol. 8, no. 1, p. 45, 2022.
[5] Y. Han and L. Wang, "Identifying barriers to off-site construction using grey DEMATEL approach: case of China," *Journal of Civil Engineering and Management*, vol. 24, no. 5, pp. 364–377, 2018.
[6] W. M. Sweileh, "Global output of research on the health of international migrant workers from 2000 to 2017," *Globalization and Health*, vol. 14, no. 1, pp. 105–112, 2018.
[7] G. Shang, L. Sui Pheng, and W. Jia Hui, "Drivers and barriers for multiskilling workers in the Singapore construction industry," *International Journal of Construction Management*, vol. 20, no. 4, pp. 289–304, 2020.
[8] B. Cheng, K. Lu, J. Li, H. Chen, X. Luo, and M. Shafique, "Comprehensive assessment of embodied environmental impacts of buildings using normalized environmental impact factors," *Journal of Cleaner Production*, vol. 334, Article ID 130083, 2022.
[9] M. Noghabaei, A. Heydarian, V. Balali, and K. Han, "Trend analysis on adoption of virtual and augmented reality in the

architecture, engineering, and construction industry," *Data*, vol. 5, no. 1, p. 26, 2020.
[10] N. Dobrovolskienė, A. Pozniak, and M. Tvaronavičienė, "Assessment of the sustainability of a real estate project using multi-criteria decision making," *Sustainability*, vol. 13, no. 8, p. 4352, 2021.
[11] M. Wang, L. Zhao, R. Du et al., "A novel hybrid method of forecasting crude oil prices using complex network science and artificial intelligence algorithms," *Applied Energy*, vol. 220, pp. 480–495, 2018.
[12] S. N. Gebremariam and J. M. Marchetti, "Economics of biodiesel production: Review," *Energy Conversion and Management*, vol. 168, pp. 74–84, 2018.
[13] D. Ayodhya and G. Veerabhadram, "A review on recent advances in photodegradation of dyes using doped and heterojunction based semiconductor metal sulfide nanostructures for environmental protection," *Materials Today Energy*, vol. 9, pp. 83–113, 2018.
[14] W. Fang, W. Fan, W. Ji et al., "Distributed cognition based localization for AR-aided collaborative assembly in industrial environments," *Robotics and Computer-Integrated Manufacturing*, vol. 75, Article ID 102292, 2022.
[15] T. Wang, S. Gao, X. Li, and X. Ning, "A meta-network-based risk evaluation and control method for industrialized building construction projects," *Journal of Cleaner Production*, vol. 205, pp. 552–564, 2018.
[16] P. Sharafi, S. Nemati, B. Samali, and M. Ghodrat, "Development of an innovative modular foam-filled panelized system for rapidly assembled postdisaster housing," *Buildings*, vol. 8, no. 8, p. 97, 2018.
[17] C. Z. Li, F. Xue, X. Li, J. Hong, and G. Q. Shen, "An Internet of Things-enabled BIM platform for on-site assembly services in prefabricated construction," *Automation in Construction*, vol. 89, pp. 146–161, 2018.
[18] M. Sakin and Y. C. Kiroglu, "3D printing of buildings: construction of the sustainable houses of the future by BIM," *Energy Procedia*, vol. 134, pp. 702–711, 2017.
[19] S. M. Sepasgozar and S. Davis, "Construction technology adoption cube: an investigation on process, factors, barriers, drivers and decision makers using NVivo and AHP analysis," *Buildings*, vol. 8, no. 6, p. 74, 2018.
[20] S. Tang, D. R. Shelden, C. M. Eastman, P. Pishdad-Bozorgi, and X. Gao, "A review of building information modeling (BIM) and the internet of things (IoT) devices integration: present status and future trends," *Automation in Construction*, vol. 101, pp. 127–139, 2019.
[21] C. Z. Li, R. Y. Zhong, F. Xue et al., "Integrating RFID and BIM technologies for mitigating risks and improving schedule performance of prefabricated house construction," *Journal of Cleaner Production*, vol. 165, pp. 1048–1062, 2017.
[22] Y. Qian, S. Chen, J. Li et al., "A Decision-Making Model Using Machine Learning for Improving Dispatching Efficiency in Chengdu Shuangliu Airport," *Complexity*, vol. 2020, Article ID 6626937, 16 pages, 2020.
[23] B. Cheng, C. Fan, H. Fu, J. Huang, H. Chen, and X. Luo, "Measuring and computing cognitive statuses of construction workers based on electroencephalogram: a critical review," *IEEE Transactions on Computational Social Systems*, pp. 1–16, 2022.
[24] P. H. Shaikh, N. B. M. Nor, A. A. Sahito, P. Nallagownden, I. Elamvazuthi, and M. S. Shaikh, "Building energy for sustainable development in Malaysia: a review," *Renewable and Sustainable Energy Reviews*, vol. 75, pp. 1392–1403, 2017.
[25] R. Yuan, F. Guo, Y. Qian et al., "A system dynamic model for simulating the potential of prefabrication on construction waste reduction," *Environmental Science and Pollution Research*, vol. 29, no. 9, pp. 12589–12600, 2022.
[26] J. Zhu, G. Wright, J. Wang, and X. Wang, "A critical review of the integration of geographic information system and building information modelling at the data level," *ISPRS International Journal of Geo-Information*, vol. 7, no. 2, p. 66, 2018.
[27] S. Alizadehsalehi, A. Hadavi, and J. C. Huang, "From BIM to extended reality in AEC industry," *Automation in Construction*, vol. 116, Article ID 103254, 2020.
[28] A. Z. Sampaio, "Enhancing BIM methodology with VR technology," *State of the Art Virtual Reality and Augmented Reality Knowhow*, pp. 59–79, 2018.
[29] S. Ahmed, "A review on using opportunities of augmented reality and virtual reality in construction project management," *Organization, Technology & Management in Construction: An International Journal*, vol. 11, no. 1, pp. 1839–1852, 2019.
[30] F. M. Dinis, L. Sanhudo, J. P. Martins, and N. M. Ramos, "Improving project communication in the architecture, engineering and construction industry: coupling virtual reality and laser scanning," *Journal of Building Engineering*, vol. 30, Article ID 101287, 2020.
[31] P. Dallasega, A. Revolti, P. C. Sauer, F. Schulze, and E. Rauch, "BIM, augmented and virtual reality empowering lean construction management: a project simulation game," *Procedia Manufacturing*, vol. 45, pp. 49–54, 2020.