Insights in Computer, Signals and Systems

Article

Research on Construction Digital Management System Based on Digital Twin

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Abstract: In the context of transformation and upgrading of the construction industry, traditional project construction management is still a complex "man-machine-environment" system engineering. The emerging digital twin technology provides new methods and technical means to realize the digitalization of construction. In order to solve the problems of redundant information of traditional construction management elements and low management efficiency, a digital model of construction management for physical space and non-physical space in the whole construction process is constructed, and an intelligent management platform for data collection and transmission of all elements of construction management is established. A process-oriented digital construction management system is proposed to realize the digital control of the construction management process. The study shows that by establishing an integrated management platform and collecting various building information elements in the whole construction process, the organic integration of construction management and digital twins can be realized, and the construction process management capabilities and management efficiency can be improved.

Keywords: digital twin; intelligent construction; digital management; building information model

Published: 21 November 2024

1. Introduction

At present, the world is experiencing a wave of digitalization represented by the Internet of Things, big data, and artificial intelligence [1]. At the same time, digital twin technology has emerged [2-6]. With the rapid development of modern information technology, the construction industry has also entered the era of informatization and digitalization, promoting the digital transformation of building design, construction, management, and operation and maintenance [7-8]. Around the world, the problem of digital transformation and upgrading of project management in the field of construction management needs to be solved urgently. At present, traditional construction management methods have problems such as difficulty in data sharing, large workload of system integration, complex construction procedures, fragmented management information, and cumbersome management processes [9]. In particular, the new requirements of project management are not compatible with the current project management system, which affects the normal construction management of buildings [10]. At the same time, with the continuous updating of personnel, machinery, materials, laws, and environmental information, the amount of data increases, further increasing the difficulty of construction management. Therefore, informatization of various elements of construction management can improve the level of management refinement and digitalization.

In recent years, new digital technologies represented by artificial intelligence, digital twins, the Internet of Things, and blockchain have gradually been applied in various engineering fields and in the construction management process at different stages [11]. In the field of construction engineering, a digital twin model of building operation and maintenance is established, and a visualization platform for building energy consumption monitoring is built; in infrastructure engineering, a digital twin model of bridges is established to evaluate and monitor the damage and safety level of prestressed concrete bridges in real time, and to carry out corresponding maintenance work [12]. In addition, there are also studies that attempt to build a digital twin model for engineering projects in the construction stage to support management decisions. For example, by building a digital twin model, information such as silo type, filling material, and location can be tracked and detected to optimize the material supply process [13].

At the same time, many scholars at home and abroad have introduced digital twin technology in the process of construction management research, and simultaneously improved the digital level of management [14]. Yang Qiliang et al. [15] proposed an extension method based on digital twin technology to build an efficient dynamic control and augmented reality human-computer interaction system for building operation and maintenance, but the required data volume is too large and the dynamic feedback process is complicated. Kim et al. [16] proposed a BIM-driven building element and facility work information management method to improve the efficiency of multi-information data extraction, but its information collection elements are different from the actual situation. Xie Linlin et al. [17] built an intelligent scheduling management platform for prefabricated building projects based on BIM+digital twin technology by integrating the Internet of Things, big data and artificial intelligence algorithms, simplifying the management process, but the platform construction system is relatively complex. Han Dongchen et al. [18] found that the problem of non -interaction between building "information physics" is due to the lack of built information reflecting the physical entity of the building in the existing BIM system, and pointed out the importance of digital twin building theory that includes design and construction information, but did not point out the specific implementation method of the construction digital management process.

The above-mentioned scholars' research on construction management driven by digital twin technology mainly focuses on the application of BIM technology in various stages of the project, or the management process of specific scheduling platforms. However, few scholars have conducted systematic research on the overall construction management theoretical system of engineering projects, including order procurement - design analysis - production and processing - construction and commissioning - later operation and maintenance.

In summary, it is necessary to build a systematic digital management system for the entire construction process of the project to achieve online perception, real-time analysis and intelligent control of various construction management elements during the construction process. To this end, this paper analyzes the integration mechanism and management architecture system of the current digital twin technology in the construction management process, and proposes a construction management implementation method for digital twins, in order to provide a theoretical reference for the management and application of digital twin technology in the entire process of engineering projects.

2. Exploration of Digital Construction Management

2.1. Building Information Model

At present, many traditional and building information model-based engineering projects are committed to achieving visual management, and BIM has gradually replaced traditional visual management tools [19]. Although BIM aims to improve construction productivity, efficiency and quality through various procedures, in the actual project management process, design, construction and management work are still mainly carried out in an office environment [20]. In addition, BIM research is mainly focused on the design stage, and BIM integrated management applications during construction are relatively rare, failing to give full play to its value in construction management [21]. Therefore, in the industrial 4.0 stage of rapid development of building intelligence and low carbonization, it is very necessary to effectively use information technology based on BIM to participate in the entire construction project management cycle.

2.2. Digital Twin Construction

The concept of digital twin (DT) was proposed by Grives at the University of Michigan in 2011. It uses information such as physical models, sensor data, and operation history to complete mapping in virtual space through multi-physical quantity, multi-scale, and multi-probability simulation to reflect the entire life cycle of the entity, focusing mainly on data and models [22]. In 2017, Tao Fei et al. expanded the traditional three-dimensional model, added two dimensions of twin data and services, and proposed a five-dimensional model of digital twins [23]. The specific model components are shown in Figure 1, and the mathematical expression of the five-dimensional model of digital twins is shown in Equation (1).

$$D_{TM} = (P_E, V_E, D_S, T_D, C_N) \quad (1)$$

In the formula: D TM is the five-dimensional model of digital twins; PE represents physical entity, VE represents virtual entity, D S represents data service, TD represents twin data, and CN represents the connection between components.

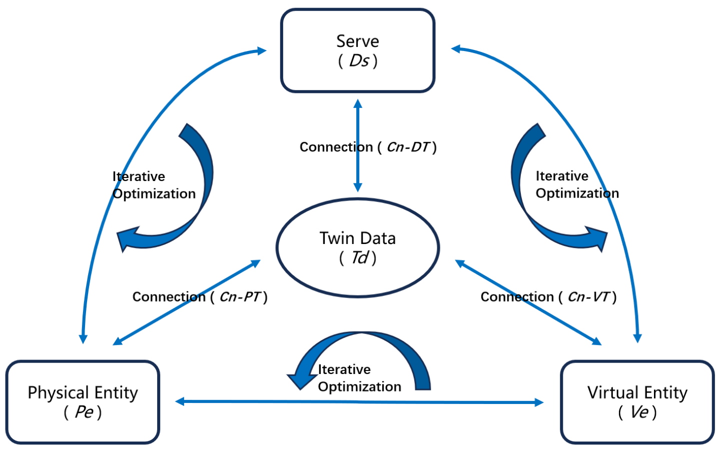


Figure 1. Five-dimensional model of digital twin.

Digital Twin Construction (DTC) is a new service based on digital twin technology, which uses management tools such as BIM, GIS, Internet of Things and intelligent algorithms to visualize construction information in the virtual world. Among them, BIM technology is used to build digital models of real physical entities, and uses Internet technology and various computer-aided software to achieve integrated management and control of architectural drawing planning, building component design, construction project construction and building digitalization.

Using the BIM model formed in the planning stage as the basic digital model support, the physical world of each link of building construction is integrated with the twin world to realize the digital twin of the entire life cycle of building construction. This method can improve the management efficiency and quality of the construction industry and promote sustainable development [24]. Digital twin construction is the specific application of digital twin technology in the construction field, and it is also an important trend in the current digital transformation and future development of the construction industry [25].

Digital twin construction (DTC) includes four basic model series [26]: physical model, logical model, component model and data model, forming a multi-model system with physical model as the core. Taking the construction process of building components as an example, first, digital twin construction collects physical model data, performs physical modeling and establishes data model, and then uses the data model for online simulation to generate a building component simulation model. Secondly, a corresponding logical model is constructed based on the physical model, and the parameters of the component model are connected with the keywords of the logical model through offline simulation. Finally, predictive simulation is performed based on the logical model fed back by the component physical model, and the real-time simulation data is converted into a data model for storage. Digital twin construction combines the basic model with the three elements of building robots, building equipment and building environment in the digital twin building to form a digital twin construction concept model as shown in Figure 2.

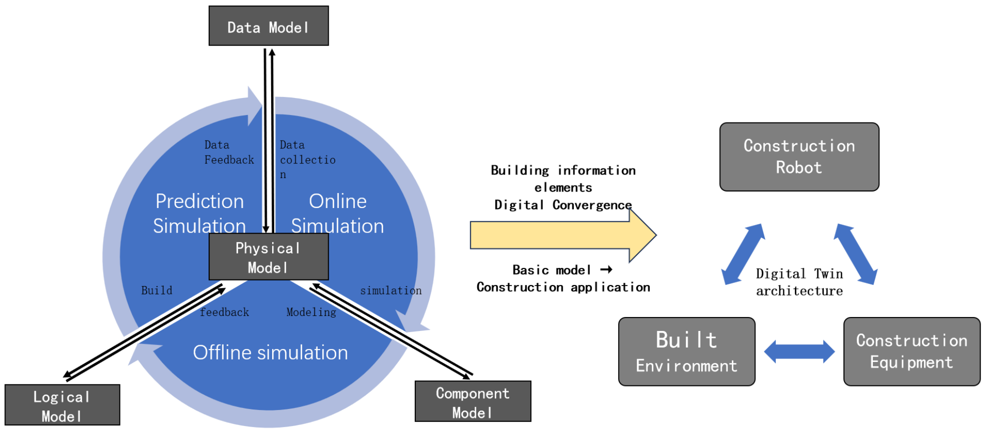


Figure 2. Conceptual model of digital twin construction.

2.3. Integration of Construction Management and Digital Twins

Digital construction management is driven by information technology and mainly uses the digital production of building components, mold machinery and other equipment as a means to optimize the entire production cycle of construction projects and achieve high-efficiency, high-quality, low-consumption and low-emission engineering construction goals.

In terms of digital twins, building management is mainly reflected in two levels: physical twins and digital twins, covering both physical and information spaces. At present, BIM is mainly used as the main information carrier, with data collected from component production to construction as the link, combined with the information of physical elements of construction management, to establish an integrated management model to achieve the organic integration of construction management and digital twins. At the same time, through data collection and precise analysis of physical entity elements, driven by the data information of digital twins, using its unique model interaction and iterative update module, through platform data interaction and model application correction, it is finally applied to element identification and data collection of construction management [27]. Based on its components, the schematic diagram of the integration mechanism of digital twins and construction management is shown in Figure 3 [28].

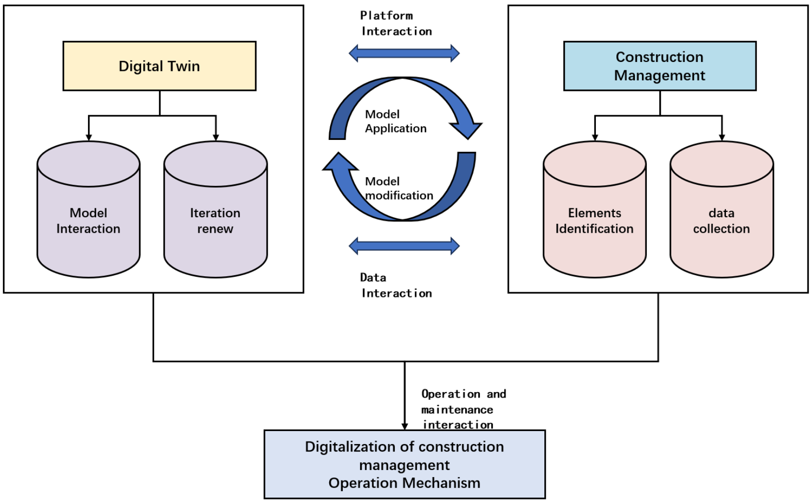


Figure 3. Integration mechanism of digital twin and construction management.

3. Construction Digital Framework Based on Digital Twin

3.1. Construction Management Digital Architecture

Through the above analysis of the digital integration mechanism of digital twin construction management, based on the self-construction of the digital architecture of "one platform, three main lines, four major sections, and N scenarios", the actual needs of the physical space are analyzed. At the same time, relying on the various types of construction information support of the project in the model library and database, as well as the powerful data processing capabilities of the information layer, digital decision-making and functional regulation of operation and maintenance management are carried out. With the platform as the center, management data, intelligent models, and BIM technology as the driving main line, a digital architecture for construction management in terms of intelligent production, intelligent construction, intelligent operation and maintenance, and intelligent management is established, and it is applied to construction production scenarios such as cast-in-place concrete or prefabricated component assembly, electromechanical installation, and steel structure, as shown in Figure 4.

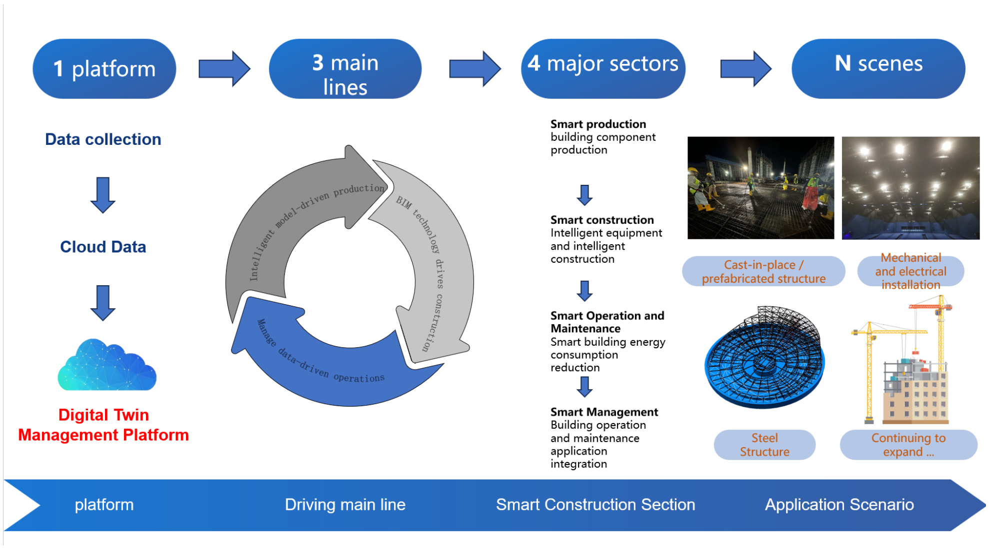


Figure 4. Construction management digital architecture.

3.2. Establishment of Process-Oriented Construction Digital Model

To achieve the synergy of various parts of digital construction management, it is necessary to establish a digital twin construction management model based on the digital construction management framework. As a specific supplement to the construction management framework, this model provides theoretical methodological support for the digitization of each module. Driven by digital twin information technology, the components of systematic construction management can be divided. In the process of building construction, according to the main production factors, project construction information can be divided into three categories: building, personnel and environment. The mathematical expression of construction management information is shown in formula (2).

$$I_{CM} = (B, P, E) \qquad (2)$$

In the formula, I_{CM} stands for construction management information; B stands for building elements, P stands for personnel elements, and E stands for environmental elements.

Among them, digital twin construction management information covers information on building materials, structures, components, electromechanical equipment, energy consumption, etc. Personnel information mainly includes personnel quantity monitoring, density distribution, and real-time positioning in the building. Environmental information mainly covers the temperature, humidity, wind speed, and light intensity of the working surface. By classifying and summarizing various types of information in the construction management process, a construction management system can be established and construction data analysis can be performed, thereby forming a classification framework for digital twin construction management information, as shown in Figure 5.

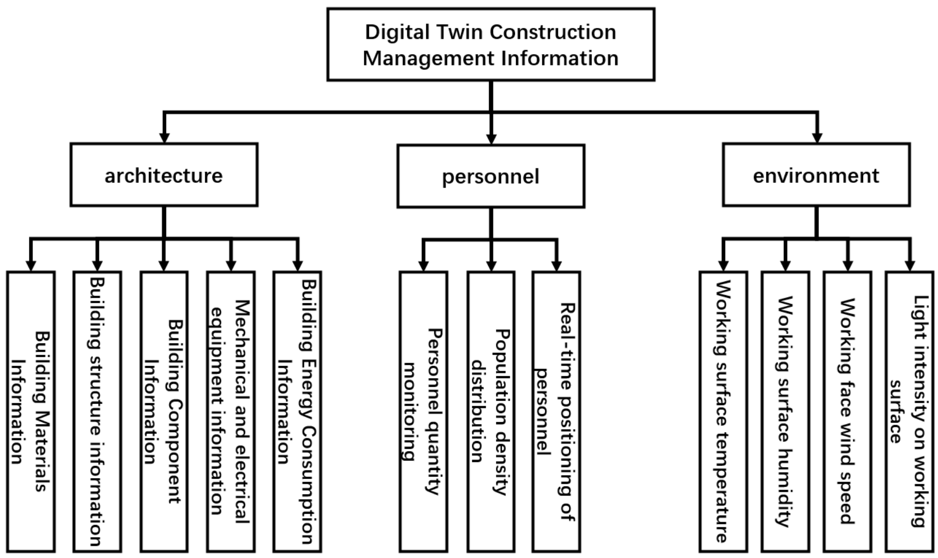


Figure 5. Collection of digital twin construction management information elements.

The process-oriented digital construction model can be divided into five modules: physical space, virtual space, twin data processing layer, functional application layer and the connection of their components. In the physical space module, data of physical entity elements such as buildings, personnel and environment are collected and transmitted to the information network module for classification and processing. In the virtual space module, a logical model is established based on the conversion concept of "physical-behavior-virtual" to achieve mutual feedback between virtual space and physical space. The twin data processing layer is responsible for the integration, preprocessing, mining and application of operation and maintenance data to promote the operation of the twin. In the functional application layer, the construction management process is presented through visualization, and the dynamic update characteristics of construction management information are used to guide the application layer to execute algorithms for decision-making. Finally, a process-oriented digital construction management model is formed, and its mathematical expression is shown in formula (3).

$$D_{CM} = (P_S, V_S, D_{PL}, F_{AL}, C_N) \quad (3)$$

In the formula: DCM is the digital model of construction management for construction management; P_S is the physical space; V_S is the virtual space; D_{PL} is the twin data processing layer; F_{AL} is the functional application layer; C_N is the connection between the components.

4. Implementation Methods of Construction Management Based on Digital Twins

4.1. Collection and Transmission of All-Factor Information During the Construction Process

The main focus of the digital twin implementation method for the construction process is to build an intelligent construction management platform to integrate and manage the digital twin system in the construction process. Current projects generally have problems such as low "physical-behavior-virtual" interactivity and difficulty in collecting actual data. To address these challenges, we use BIM models from design, deepening, production, and construction, combined with building material information such as size, material, and performance, to apply or develop relevant professional software. Through the design, production, and construction management systems, the data required to build digital twins is comprehensively collected to make up for the problems of insufficient data collection and poor interactivity of digital twin physical entities in construction management. The independently developed digital twin construction intelligent management platform has the architecture shown in Figure 6.

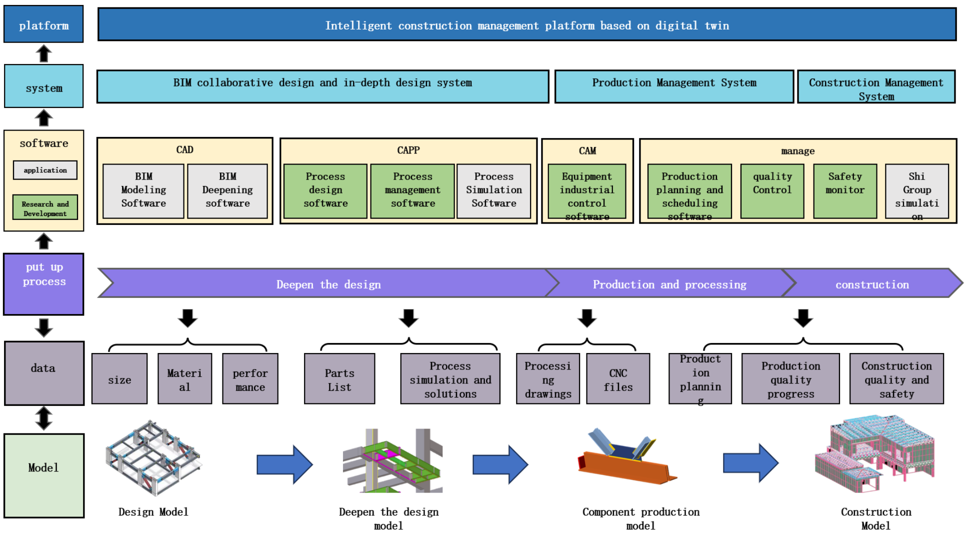


Figure 6. Construction intelligent management platform based on digital twin technology.

The construction intelligent management platform based on digital twins has the following functions: converting physical entity models into virtual information models, and using intelligent simulation modules based on digital twins to participate in the entire process from building component production to building operation management. The platform can provide real-time feedback and correction of data and behavior information during the construction process, effectively guiding the planning, construction and operation of physical buildings. Through the digital twin visualization modeling tool, an intuitive human-computer interaction interface is developed to facilitate project management technicians to fully understand the construction process of the project.

In the entire construction management operation process, element identification and data collection are key steps in digital management. Through model application and correction, the various elements in the construction management digital operation system are integrated, the platform and data interaction is realized, and the integration of digital twins and construction management is promoted [29].

In the entire construction management process, the collection and management of various types of information are realized by connecting the twin data processing layer and the functional application layer. All types of information in the physical entity space are collectively referred to as I p, and the mathematical expression is shown in formula (4).

$$I_P = \begin{pmatrix} B_P \\ P_P \\ E_P \end{pmatrix} = \begin{pmatrix} B_{P1} & B_{P2} & .. & B_{PX} \\ P_{P1} & P_{P2} & .. & P_{PY} \\ E_{P1} & E_{P2} & .. & E_{PZ} \end{pmatrix} \quad (4)$$

Where: B_P, P_P, E_P represent the building, personnel, and environment information in the physical space respectively; B_{P1}, B_{P2} ⋯ B_{PX} represents the building information in the physical space; P_{P1}, P_{P2} ⋯ P_{PY} represents the personnel information in the physical space. E_{P1}, E_{P2} ⋯ E_{PZ} represents the environment information in the physical space.

For the physical entity information collected during the construction process, the physical model and virtual model in the digital twin building are combined through a platform that can perform data interaction and model correction, and data is transmitted in a logical order from the basic model to the construction application. At the same time, simulation of various physical entity information is performed in the virtual space to aggregate and form digital twin information, and its mathematical expression is shown in formula (5).

$$I_{DT} = \begin{pmatrix} B_{DT} \\ P_{DT} \\ E_{DT} \end{pmatrix} = \begin{pmatrix} B_{DT1} & B_{DT2} & .. & B_{DTX} \\ P_{DT1} & P_{DT2} & .. & P_{DTY} \\ E_{DT1} & E_{DT2} & .. & E_{DTZ} \end{pmatrix} \quad (5)$$

In the formula: I_{DT} represents digital twin information, B_{DT}, P_{DT} and E·represent the building, personnel and environment information in the digital twin virtual space respectively; B_{DT1}, B_{DT2} ⋯ B_{DTX} represents the building information in the digital twin virtual space; P_{DT1}, P_{DT2} ⋯ P_{DTY} represents the personnel information in the digital twin virtual space; E_{DT1}, E_{DT2} ⋯ E_{DTZ} represents the environment information in the digital twin virtual space.

4.2. Construction Process Twin Construction and Operation

In the process of the continuous development of the modern construction industry, using the collected physical entity element information to process and analyze data and build a demonstration project intelligent management platform has become a hot topic in the industry [30]. However, during the project construction process, non-physical elements that cannot be collected will appear, and they play an important role in the entire project construction. Therefore, in the process of building and operating digital twins, the impact of such non-physical elements needs to be considered.

Based on the digital model of construction management, simulation mapping of the actual operation and maintenance process can be achieved. Through the algorithm module preset by the platform, the status of each element information is analyzed, and corresponding decisions are made at the execution site. In the process of establishing the twin model, the physical space corresponds to the actual operation and maintenance process of the building, while the virtual space establishes a virtual model based on the real-time collected information. Through the above analysis, the mathematical expression of the twin of the construction management process is constructed as shown in formula (6).

$$PCV = \begin{pmatrix} P \\ C \\ V \end{pmatrix} = \begin{pmatrix} I_{P1} & I_{P2} \\ C_{N1} & C_{N2} \\ D_{CM1} & D_{CM2} \end{pmatrix} \quad (6)$$

Where: P, C, and V represent physical space, digital twin connection mode, and virtual space, respectively. I_{P1} and I_{P2} represent the entity element information and non-physical element information of the physical space, respectively. C_{N1} and C_{N2} represent the connection mode between the construction entity and non-entity and the digital twin space, respectively. D_{CM1} and D_{CM2} represent the construction management digital model of the physical space and non-physical space for the construction management process, respectively.

4.3. Twin Data Storage and Management During Construction

By collecting information on all elements of the construction process, a twin of the construction process is constructed, and the model algorithms corresponding to the digital twins such as physics, behavior, and geometry are used to form calculation results and feed them back from the twin data processing layer to the functional application layer, thus realizing a closed loop of the digital twin data transmission process.

While executing the decision, the final feedback-corrected physical entity information and the information in the digital twin virtual space are classified and stored according to the physical entity space, mainly covering three categories: buildings, personnel and environment. Taking buildings as an example, it can be further subdivided into subcategories such as building materials, structures, components and equipment. Personnel and environmental information is relatively difficult to collect, and their data has the characteristics of dynamic update. Therefore, for massive, multi-source, and heterogeneous raw data that require real-time feedback and update, the Internet of Things sensor technology can be used. This technology can pre-process and standardize the raw data collected from the physical space, the model data and simulation data in the digital twin virtual space through a digital management platform [31]. Then, through data fusion, mining and cluster analysis, the final decision data set is obtained, and the data set storage is completed at the same time.

DTP (SM) based on digital twin technology can be established, which is mainly used for the data storage of physical entity space and digital twin in the construction intelligent management platform mentioned above. In addition, it also includes the data storage of dynamically updated physical entity information such as buildings, personnel, and environment during the construction process and the corresponding twin information. The data storage management platform mainly includes six steps: data recognition (DR), data preprocessing (DP), data fusion (DF), data analysis (DA), data output (DO), and data storage (DS). The mathematical expression of the construction data storage and management platform (DTP SM) based on digital twin is shown in formula (7).

$$DTP_{SM} = (D_R, D_P, D_F, D_A, D_O, D_s) \quad (7)$$

5. Case Applications

By constructing a digital twin of the construction process and establishing an operating mechanism from information collection and transportation to twin-driven operation, and then to the storage and management of twin data generated by operation, a large amount of data is obtained from non-physical space decisions and requires management action feedback through physical space. Therefore, the use of an operational digital platform can realize the combination of non-physical space and physical space.

5.1. Building a Digital Platform Technology Architecture

Comprehensive construction management information, digital architecture, intelligent management platform, and construction management digitalization and operation and maintenance management platform can be divided into four levels from the basic data collection layer to the top application layer according to the data characteristics of the digital twin and construction management process: data collection layer, data processing layer, digital twin function layer, and human-computer interaction layer [32]. These levels are closely linked, and the structure of each level is built on the basis of the previous levels. According to the above hierarchical classification, the technical architecture of the digital management platform for the construction process based on digital twin technology is shown in Figure 7.

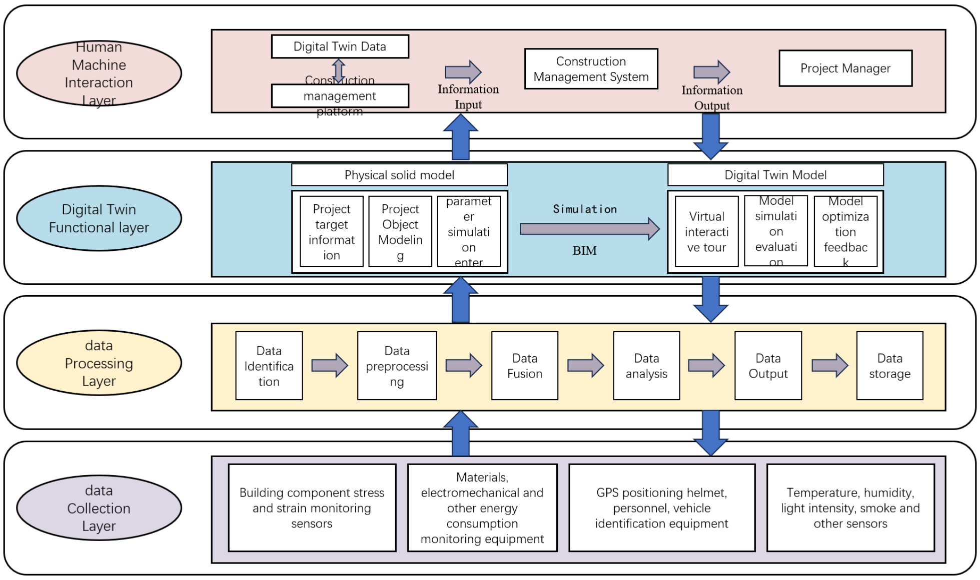
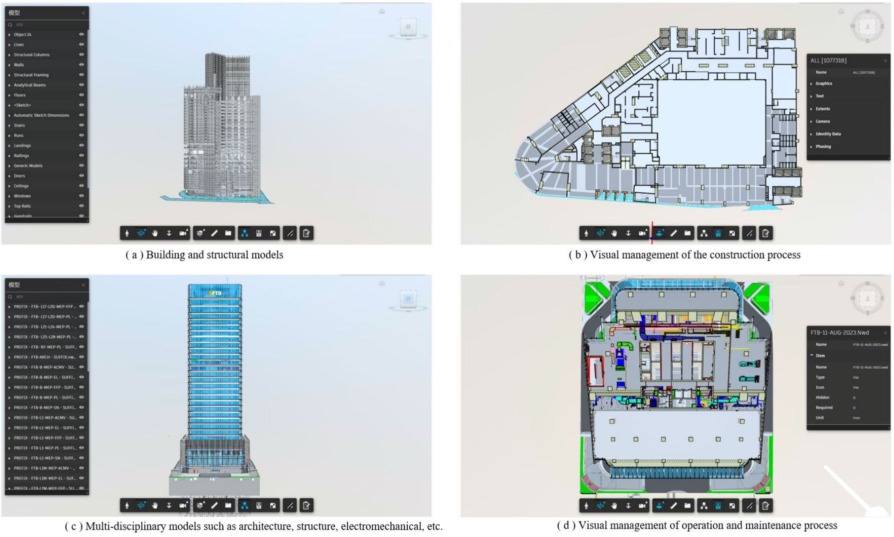


Figure 7. Technical architecture of digital management platform.

In the intelligent management platform, the data collection layer is the foundation. Through various sensors and IoT connections, such as infrared sensors and laser scanners, the system platform can obtain sufficient and accurate data support and reflect the status of physical entities in real time [33-35]. The data processing layer is the information screening layer, which transfers data from the collection layer to the digital twin function layer. By statistically analyzing the information data in the construction process, classifying and standardizing it, it provides a dynamically updated and accurate data information flow. The digital twin function layer is the core of the management platform and the key node connecting the physical and virtual spaces. Based on BIM technology and IoT technology, multi-scale levels are modeled and simulated, twin data is integrated, and the virtual model and the physical model are interactively mapped through intelligent algorithms to achieve information feedback and update synchronization. The human-computer interaction layer is the direct docking level between the management platform and the manager, realizing the visual control of the resource allocation of the construction project. By intuitively displaying the construction management process of the entire project, managers can quickly issue decision instructions to the management platform system to achieve digital control of the entire project process.

5.2. Construction of Digital Platform Applications

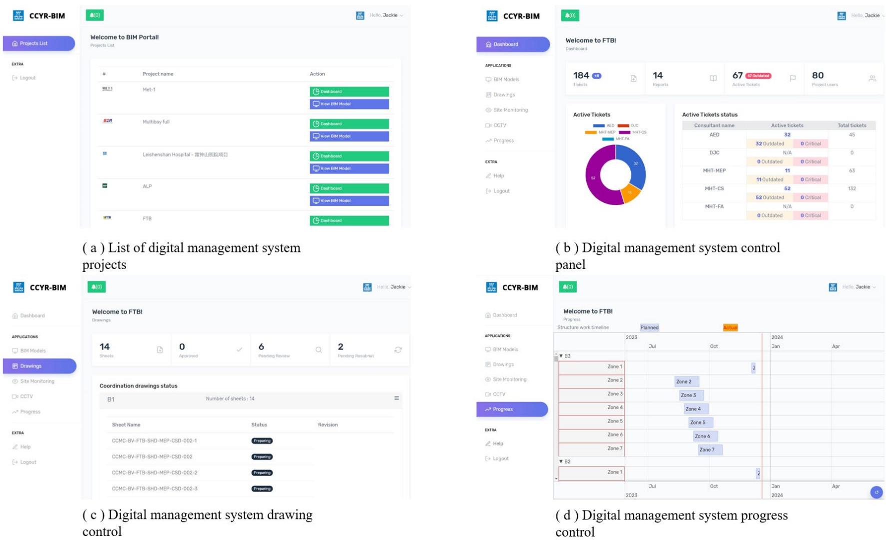
Based on the analysis of the construction management theory system and implementation methods, a case application of a construction management platform based on digital twins was conducted around a large-scale construction project. Driven by digital twin technology, by establishing multi-professional models such as architecture, structure, and electromechanical, the construction process of the entire project construction process is visually managed, as shown in Figure 8.



(a) Building and structural models
(b) Visual management of the construction process
(c) Multi-disciplinary models such as architecture, structure, electromechanical, etc.
(d) Visual management of operation and maintenance process

Figure 8. Visual management of construction and operation and maintenance process.

At present, the comprehensive application of BIM technology as the core of management runs through the entire process of building construction. Through the zoning control mode of safety management, quality management, technical management, etc., the comprehensive application of digital information technology such as BIM can, on the one hand, make the project construction, personnel, environment and other management elements reasonably controlled; on the other hand, it can also enable managers to select reasonable construction plans and solve construction problems in advance through construction simulation before they occur; therefore, building a comprehensive project management system based on digital twins can enable digital twin technology to better collect and process multi-source heterogeneous engineering data at all stages of project construction, realize digital management of project construction, minimize the risk of project delays, and centrally manage project construction on a visual digital twin platform, thereby optimizing its construction cost. The construction digital management system is shown in Figure 9.



(a) List of digital management system projects
(b) Digital management system control panel
(c) Digital management system drawing control
(d) Digital management system progress control

Figure 9 Construction of digital management system.

In actual project construction applications, based on the construction digital architecture and intelligent management platform, using the management of interoperable process data, and taking the currently highly applied BIM technology as the digital twin driving core, a complete construction management system is established from project demand analysis to order procurement - design analysis - production and processing - construction and commissioning - post-operation and maintenance, realizing the entire project construction design, production, and construction as the main line, and establishing a digital twin technology application system for the entire construction process, as shown in Figure 10.

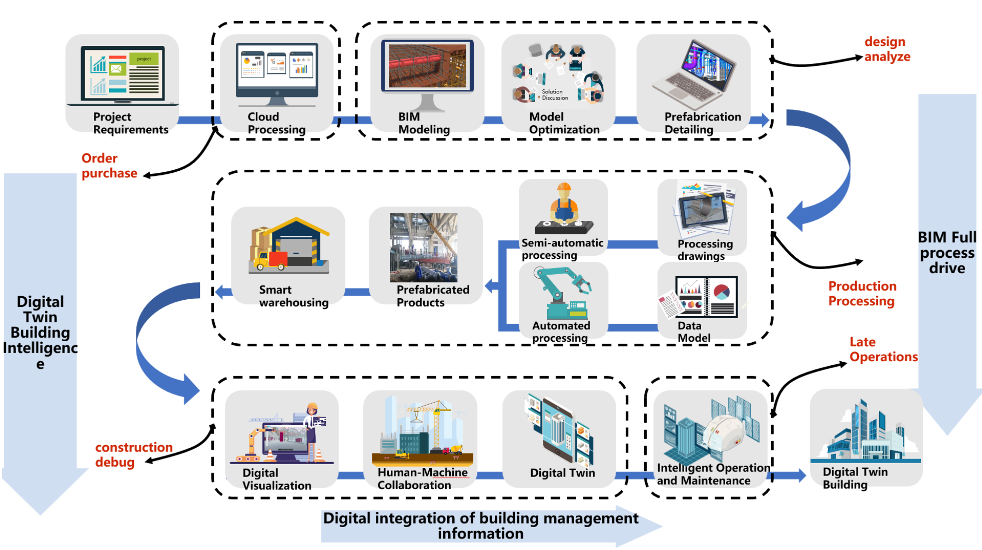


Figure 10. Digitalization of construction management under digital twin technology.

By adopting the digital twin-based construction digital management method and system, the personnel configuration of each stage of construction in the actual construction process of a certain project is used as the cost basis, and the number of various types of workers on site is monitored and collected. Among them, the period with the largest number of laborers is the sixth month of construction, with 562 workers on site, mainly decoration and electromechanical installation, and the monitoring data of the number of prefabricated grouting workers is 42. In the seventh month of construction, the project applied the digital twin construction management system and the intelligent digital management platform to regulate the personnel, and the number of workers on site was optimized to 510, and the monitoring data of the number of prefabricated grouting workers was 21. Compared with the traditional construction platform and its operation and maintenance management mode, by using the above-mentioned construction management system and digital control management platform, and integrating digital twin technology, the number of workers in the management process can be controlled, as shown in Figure 11. The results show that by applying the construction management system, the project can save up to 10.2% of time cost and reduce the cost of personnel use by about 9.2%. According to the ratio of personnel, it can save about 8.9% of resource energy consumption per capita, which ensures that the construction process of the project is always within the controllable range. At the same time, it also avoids a series of losses caused by slow construction progress and chaotic construction platform management.

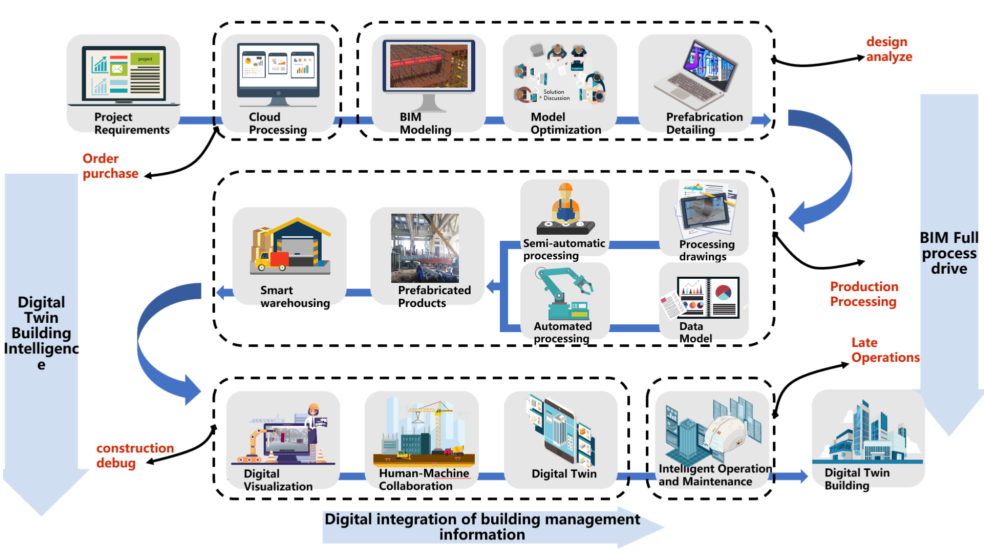


Figure 11. Labor force allocation diagram for each construction stage.

5.3. Difficulties and Challenges in Digital Construction Management

Digital twin technology is a two-way mapping between virtual and real, enabling dynamic interaction and real-time connection between the two. It is a digital expression corresponding to the physical system [36]. Through the case application of a construction management platform supported by digital twin technology around a large-scale construction project, combined with the above analysis of the actual building element data of digital construction management, the challenges of digital management are summarized.

First, existing work only studies on on-site situation perception and data modeling, and is still limited to BIM technology application and visual video monitoring. It has not realized a digital and integrated construction site construction model, nor has it formed a complete digital construction management system for the construction process. Secondly, the product-organization-process (POP) model currently developed for digital construction management also has a series of problems such as incomplete data collection and process management system. Finally, key technologies in the semantic modeling and mapping of building elements, the information-physical fusion of dynamic and real-time interaction of digital twin models, and the integration of physical entities, virtual models and service systems need to be tackled.

This model mainly targets digital twins of different construction management processes. By collecting information on physical elements and non-physical elements in the physical space, it constructs a relationship matrix and can perform matrix multiplication operations to summarize the construction management digital model data set of various physical entity information of buildings, personnel and environment in the virtual space. Ultimately, it realizes the application of construction management digital models for physical space and non-physical space in the construction management process.

6. Conclusion

In view of the low management efficiency and insufficient management accuracy of various construction elements in the traditional construction process, this paper constructs a digital twin model of personnel allocation in the construction phase, combines BIM and Internet of Things technology, and establishes a construction data storage and management platform (DTPSM) based on digital twin technology to optimize the number of personnel in each stage of the actual construction of the project. Driven by digital twin technology, it can realize the information collection and data circulation of elements such as buildings, personnel, and environmental models in physical space and virtual space. It provides new ideas for the construction project management system.

However, the digital twin modeling method in this paper still has certain limitations. The main reasons are that the data collection and processing in the construction process is not complete, the data storage space is insufficient, and the key technology application standards are not yet mature. In subsequent research work, we will conduct in-depth research on the digital management framework of the whole process of construction based on digital twins, and incorporate more influencing factors of the construction site into the digital twin model to solve the problem of allocating multiple resource elements in the construction process.

References

1. Wang Dongwei. "Digital transformation" will bring new development opportunities to the smart building industry[J]. Intelligent Building, 2021(1): 25-26.
2. Li Xinru, Hu Yajie, Liu Xin, et al. Research on the application of smart construction site architecture based on digital twin technology: Taking Jinhui Experimental Primary School project as an example[J]. Fujian Architecture, 2023, 297(3): 127-130.
3. Liu Jiqiang, Zhang Yuyu, Wang Xuejian. Research on intelligent management of urban rail transit construction based on digital twins[J]. Modern Urban Rail Transit, 2021(S1): 120-125.
4. Sun Yongfang, Ding Jie. Research on digital twin technology for intelligent construction of bridge precast beam yard: A case study of SG5 section of Beijing-Xiongan Expressway Network[J]. Fujian Architecture, 2021, 276(6): 109-113.
5. Jiao Ke, Du Zuolong, Yang Xin, et al. Research and practice of digital intelligent construction system for the whole construction process[J]. Information Technology in Civil Engineering and Architecture, 2021, 13(2): 1-6.
6. Han Qing, Xu Xiang, Sun Baodi, et al. Research on the application of digital twin intelligent construction system for engineering projects based on CIM platform[J]. China Construction Informatization, 2022, 153(2): 34-38.
7. MOHAMMADI, SINA, TAVAKOLAN, MEHDI, ZAHRAIE, BANAFSHEH. An intelligent simulation-based framework for automated planning of concrete construction works[J]. 2022, 29(2): 916-939.
8. Luo Qiming, Hua Jianmin, Huang Lepeng, et al. Visualization analysis of domestic and foreign smart construction research based on knowledge graph[J]. Journal of Building Structures, 2021, 42(6): 1-14.
9. Liu Zhansheng, Shi Guoliang, Du Xiuli, et al. Theoretical system and implementation method of intelligent operation and maintenance based on digital twins [J]. Chinese Journal of Civil and Environmental Engineering, 2024, 46(01): 46-57.
10. Jiang Xueyan. Application research of smart building operation and maintenance management platform: taking a large commercial complex project as an example [J]. Construction Economy, 2021, 42(9): 78-82.
11. Ding Lieyun. Empowering integrated infrastructure to promote industry transformation [J]. China Surveying and Design, 2020(10): 15–18.
12. Shim C, Dang N, Lon S, et al. Development of a bridge maintenance system for prestressed concrete bridges using 3D digital twin model [J]. Structure and Infrastructure Engineering, 2019, 15(10): 1319–1332.
13. Sun J, Tian Z, Fu Y, et al. Digital twins in human understanding: A deep learning-based method to recognize personality traits [J]. International Journal of Computer Integrated Manufacturing, 2020, 33: 1–14.
14. Zheng Qiuyi, Zhou Guangdong, Liu Dingkun. Establishment method of temperature - displacement correlation model of long-span arch bridge based on long short-term memory neural network [J]. Engineering Mechanics, 2021, 38(4): 68-79.
15. Yang Qiliang, Ma Zhiliang, Xing Jianchun, et al. Building information model extension method for cyber-physical integration[J]. Journal of Tongji University (Natural Science Edition), 2020, 48(10): 1406-1416.
16. KIM, KARAM, KIM, HYUNJOO, KIM, WOOYOUNG, et al. Integration of ifc objects and facility management work information using Semantic Web[J]. Automation in construction, 2018,87(Mar.):173-187.
17. Xie Linlin, Chen Yajiao. Research on intelligent management platform for prefabricated building project scheduling based on BIM+digital twin technology[J]. Construction Economy, 2020, 41(09): 44-8.
18. Han Dongchen, Zhang Hong, Liu Yan, et al. From BIM to BDT: A study on the conception of building digital twin (BDT)[J]. Journal of Architecture, 2020(10): 95-101.
19. ALGAN TEZEL, ZEESHAN AZIZ. Visual management in highways construction and maintenance in England[J]. Engineering construction & architectural management, 2017, 24(3): 486-513.
20. OZAN KOSEOGLU, ELIF TUGCE NURTAN-GUNES. Mobile BIM implementation and lean interaction on construction site: A case study of a complex airport project[J]. Engineering construction & architectural management, 2018, 25(10): 1298-1321.
21. SANDRA MATARNEH, FARIS ELGHAISH, FARZAD POUR RAHIMIAN, et al. Automated and interconnected facility management system: An open IFC cloud-based BIM solution[J]. Automation in construction, 2022,143(Nov.):104569.1-104569.19.
22. JIANG, FENG, MA, LING, BROYD, TIM, et al. Digital twin and its implementations in the civil engineering sector[J]. Automation in construction, 2021,130(Oct.):103838.1-103838.16.
23. Tao Fei, Liu Weiran, Zhang Meng, et al. Digital twin five-dimensional model and its application in ten fields[J]. Computer Integrated Manufacturing Systems, 2019, 25(1): 1-18.

24. Du Mingfang. Research on smart building system integration based on digital twin[J]. Information Technology in Civil Engineering and Architecture, 2020, 12(6): 44-48.
25. Zhang Xuekun, Luo Yunshan. Application and practice of digital twins in intelligent construction[J]. Chongqing Architecture, 2021, 20(S1): 73-76.
26. Du Mingfang. Digital twin building: realizing integrated building management and control[J]. China Construction Informatization, 2020(20): 40-43.
27. Hu Zhenzhong, Leng Shuo, Yuan Shuang. Intelligent operation and maintenance management method based on BIM and data-driven[J]. Journal of Tsinghua University(Science and Technology), 2022, 62(2): 199-207.
28. Liu Zhansheng, Shi Guoliang, Du Xiuli, et al. Theoretical system and implementation method of intelligent operation and maintenance based on digital twins [J]. Chinese Journal of Civil and Environmental Engineering, 2024, 46(1): 46-57.
29. LIU Z S,ZHANG AS,WANG WS.A framework for an indoor safety management system based on digital twin[J].Sensors,2020,20(20):5771.
30. Lu Y, Liu C, Wang KI, et al. Digital twin-driven smart manufacturing: connotation, reference model, applications and research issues [J]. Robotics and Computer-Integrated Manufacturing, 2020, 61: 1–15.
31. MADNI A, MADNI C, LUCERO S. Leveraging digital twin technology in model-based systems engineering [J]. Systems, 2019, 7(1): 7.
32. Xie Linlin, Chen Yajiao. Research on intelligent management platform for prefabricated building project scheduling based on BIM+digital twin technology[J]. Construction Economics, 2020, 41(9): 44-48.
33. Cha Y, You H. Torsion sensing based on patterned piezoelectric beams [J]. Smart Materials and Structures, 2018, 27(3): 1–15.
34. Wang Li, Wu Tong. Research on deep crack monitoring of concrete structure based on optical fiber sensing technology[J]. Laser Journal, 2020, 41(11): 193–197.
35. Fang W, Zhong B, Zhao N, et al. A deep learning-based approach for mitigating falls from height with computer vision: Convolutional neural network [J]. Advanced Engineering Informatics, 2019, 39: 170–177.
36. Lu Y, Liu C, Wang KI, et al. Digital twin-driven smart manufacturing: connotation, reference model, applications and research issues [J]. Robotics and Computer-Integrated Manufacturing, 2020, 61: 1–15.