Research Article

Visualization of Component Status Information of Prefabricated Concrete Building Based on Building Information Modeling and Radio Frequency Identification: A Case Study in China

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In view of the problems such as the basic properties, usage, and location of prefabricated concrete building components, which are easy to be omitted, missed, and difficult to query in the field management, this study introduces building information modeling (BIM) and radio frequency identification (RFID) technologies to visualize the state information of prefabricated concrete components, such as component type, manufacturer, location, and temperature. In the design stage, a new RFID family can be built in the actual model in order to solve the lack of definition of RFID family through the Industry Foundation Class (IFC) standard, and the databases of BIM and RFID can be connected with C# language, realizing the effective integration of the two engineering technologies. In the application stage, through the secondary development of Revit, the information connection between PC terminal and RFID equipment is completed, and the component data collected by RFID tags are transmitted to the BIM model to realize the integration and visualization of prefabricated component state information. In this study, the traceability of prefabricated components of prefabricated concrete buildings can be improved, providing a basis for quality responsibility tracking in the later period, reducing unnecessary waste of human and material resources and helping to maximize economic benefits.

1. Introduction

In order to break through the bottleneck of extensive management and labor-intensive development of the traditional construction industry and realize the sustainable development of the construction industry, China has issued a series of policies and measures to promote the development of prefabricated buildings [1, 2]. The prefabricated component, which runs through the whole supply chain of residential construction, is the basic element of prefabricated concrete buildings [3]. So it is very important to systematize the information of prefabricated components for realizing the industrialization of construction. Currently, due to imperfect information technology means and lack of prefabricated component state information specifically for

information collection and transmission mechanism, the personnel at the scene of the prefabricated concrete component management method need graphics of query component object associated with the graphical information (including drawings, quality assurance files, artifacts, and maintenance records) [4]. This information is usually provided by the prefabricated construction firms, which tends to be original. In paper formats, information cannot effectively be correlated and updated in a timely manner. So managers need to spend a lot of time querying and receiving authenticated information; hence, large amounts of resources are often wasted on nonvalue-added work [4, 5]. Therefore, it is very necessary to establish efficient information management methods for prefabricated components and realize the integration and visualization of each prefabricated

component information management in the whole process of project management by combining cutting-edge technologies so as to improve the production quality and management efficiency of components.

BIM is mainly used to process and analyze the data information of various components in the model through the combination of related software and technical equipment so as to provide a platform for project participants to share information and resources and optimize the process management of the project [6–8]. RFID is a noncontact automatic identification technology used for information collection, which is usually composed of an RFID reader and RFID tag. The application of this technology can track and manage the whole life cycle of prefabricated components, ensure the timely collection, transmission, analysis, and processing of component information, and optimize the supply chain while improving the data flow [9]. BIM and RFID technologies have their own advantages and disadvantages in the application of prefabricated component information management, and their combination can complement each other [10, 11]. At present, domestic and foreign scholars have little research on the application of BIM and RFID technologies in the information management of prefabricated building components. Most of them have only established the system framework integrating BIM and RFID technologies, and rarely systematically integrate the actual effective information of prefabricated components and present it to managers in a visual form [12–15]. With the advent of the era of big data, this study has important theoretical significance for promoting project management informatization and building industrialization.

In this study, RFID tags are mainly used to collect the component status information from the factory processing to the postcompletion operation, which includes component type, manufacturer, component ID, location, temperature, and humidity. And at the data level, the IFC standard was used to build a new RFID family, and the C# language was used to connect the two databases, which realizes the effective integration of the two engineering technologies. The newly built RFID family can be identified by the BIM model so that managers can not only clearly see the status of RFID tags embedded in each component but also track the corresponding position of prefabricated components with RFID tags in real time. The application of BIM and RFID technologies in prefabricated components' information management improves the problems of low manual recording efficiency, slow data exchange, and inconvenient information sharing in the traditional construction site, makes the data acquisition mode change from manual to automatic operation, and realizes timely update and tracking feedback of component information state.

The rest of this paper is organized as follows: Section 2 reviews previous research on the application of BIM and RFID technologies and the management process of prefabricated building projects. Section 3 introduces the data integration principle of BIM and RFID technologies and puts forward the information query process of precast concrete components based on BIM and RFID technologies. In Section 4, a precast building in Shanghai is taken as an

example. Section 5 concludes the study, and Section 6 discusses the limitation and future directions.

2. Literature Review

2.1. Research on the Management of Prefabricated Components Based on BIM Technology. Prefabricated buildings need to ensure the close coordination between prefabricated production links and field construction links so that the prefabricated component production links can achieve fine and quantitative management [2]. Some foreign scholars focus on the application of BIM technology to improve the intelligent level of prefabricated component production process and achieve fine management so as to improve the efficiency of prefabricated components production [6, 7]. Mohammed and Liu made use of the visualization advantage of BIM technology, integrated the schedule plan, and guided by the task of the factory, proposed the BIM-4D simulation framework to carry out fine management on the production process, quality, and quantity of prefabricated components in the factory but lacked in the development of BIM technology platform [16]. In addition, Azimi et al. put forward a schedule plan for the production of prefabricated components outputted by the MCMPPro and imported them into the process of the whole optimization model. It can form the factory value stream mapping so as to realize the integration of BIM technology and lean construction technology to achieve concrete prefabricated production process optimization, the basic goal of value-added product [17]. However, the prefabricated component data extracted by BIM technology in this study are limited and cannot be dynamically managed.

China's prefabricated buildings are still in the initial stage of development, with the prefabrication of components as the main part, and the prefabrication level of factories is generally not high [1, 18]. Heng Li proposed the IKEA model of the manufacturing industry and VP technology into a prefabricated construction process [19]. Ting Gong analyzed the application of BIM in different building types and proposed a new mode of combination between BIM technology and the design and production of prefabricated building components [20], but a large number of component data contained in the BIM model are not fully utilized. Yang used BIM software platform for modeling and explored the application points of BIM technology in prefabricated buildings. The conclusion shows that BIM technology can improve the site construction efficiency, but the application scheme still needs to be deepened [21]. Arthur examined emulating or simulating large numbers of IoT devices to explore the potential of effectively linking BIM with the IoT [22]. Most of these studies only established a conceptual system without in-depth analysis and development of the research system through API.

2.2. Research on Information Tracking Based on RFID Technology. RFID technology uses antennas to transmit and receive radio frequency signals. Data communication can be completed through noncontact space so as to achieve remote

control and management. It has the advantages of strong environmental adaptability, large data storage capacity, long-distance reading and writing, and long life [9, 23]. In recent years, the research on RFID technology in building information tracking management mainly includes the following: Jang and Skibniewski developed an RFID embedded system by combining radio and ultrasonic signals to track building assets (materials and equipment) [24], but the system is mainly based on the RFID equipment itself, without considering the integration with BIM technology. Domdouzis has developed a 3D model based on RFID technology for managing buried materials [25]. Some researchers discussed the application of RFID automatic tracking tube spools and other valuable items and developed a system for on-site inspection [26, 27], but the data storage function of RFID tags is not further analyzed. Li and Becerik-Gerber made a comparative analysis of eight positioning technologies, and based on the comprehensive consideration of accuracy, affordability, wireless communication, context independence, data storage, power supply, and other key issues, they concluded that RFID technology is the most appropriate indoor position sensing technology [28]. Most of these studies start from the inherent positioning function of RFID technology and do not delve into the information collection and storage functions of RFID tags.

For RFID technology in the management of prefabricated building components, Ke developed a prefabricated production management system based on RFID [29]. Chin provides a developed information system based on RFID and 4D CAD to manage the production, transportation, installation, and other processes of prefabricated components [30]. Valero and Adán introduced a method to locate prefabricated components through RFID and GIS technologies, but the experimental conditions were too simple [31]. The application of RFID technology to the tracking management of prefabricated components helps us to optimize the construction of the supply chain. However, the readability of data collected by RFID tags is often not intuitive enough to be associated with the actual component model.

2.3. Integrated Management of BIM and RFID in the Field of Construction. In order to give full play to the overall benefits of BIM and RFID technologies, some domestic and foreign scholars have discussed and studied the integration and application of BIM-RFID technology. In terms of the integration of BIM and RFID data, Motamedi et al. studied the classification and presentation of RFID tag data in BIM database, as well as the standards for the storage of BIM data in RFID, which proved the feasibility of data integration of BIM and RFID [32]. Xie evaluated the technology of existing RFID equipment, studied the integration of RFID and BIM technologies, and proposed the connection mode between RFID and BIM database, which provided a certain theoretical reference for this study [33]. RFID technology can realize the integration with the BIM model and provide good support for component identification, positioning, and

information management [12, 13, 33]. At present, the application and research status of BIM-RFID technology in practical engineering is shown in Table 1.

2.4. Summary. Through literature research, it is found that BIM and RFID technologies have their own advantages and disadvantages in practical engineering application, and their combination can complement each other. BIM, as a carrier of building information, has limited data of prefabricated components. Combining it with RFID technology to collect and process information of prefabricated components and visually present the basic state of prefabricated components will benefit a lot for site managers.

The application research of BIM-RFID technology in many aspects of the construction field has been carried out one after another, and some research results have been achieved. However, most of the studies remain in the theoretical framework, and the application of RFID technology is also limited to its positioning function. There are still few studies on the application of BIM-RFID technology in the information management of prefabricated components, lacking systematic and breakthrough achievements. With more promotion of BIM and RFID technologies in the construction industry, the current research cannot meet the demand for intelligent management of prefabricated building components, so it is urgent to conduct systematic research on the information visualization management of prefabricated components based on BIM and RFID technologies.

3. Design Flow

3.1. Data Integration between BIM and RFID Technologies. Data integration with BIM as the core is essentially the integration of models and ultimately the integration of software or technology [3, 39]. Currently, BIM-centric software integration solutions can roughly be divided into two categories:

- (i) Interface integration: this solution is designed to connect and integrate two different software systems or modules through software interfaces to achieve the transfer of building information contained in the BIM model. As one of BIM's core modeling software, Revit is also the BIM software with the largest number of users. Software developers reserve a large number of APIs for them. Secondary developers can call these APIs to achieve internal access to model elements, project documents, applications (element, document, and application), and related operations.
- (ii) System integration: it refers to the integration of multiple independent software for the purpose of building a BIM information system. According to its integration depth, it can achieve interface integration, and deeper level can be achieved. By integrating the data, all the building models contained in the software model are stored in a model, and all software shares a database, thus forming a powerful data integration and collaborative management platform.

TABLE 1: Research status of integrated management of BIM-RFID technology.

Researchers	Main contributions	Limitations
Guo et al. [12]	Based on BIM-RFID, a real-time location and safety warning system model for construction workers is proposed	The model is only a theoretical framework, and the warning function is not verified by examples
Gao and Pishdad-Bozorgi [13]	Building equipment operation and maintenance management system based on BIM-RFID technology is established	Most of the construction equipment information collected in this system comes from the operation and maintenance management manual, and the information processing is relatively inefficient
Chan et al. [14]	The idea of combining BIM and RFID technologies for real-time data integration is put forward	The integration of the two data is not carried out through a database terminal
Li et al. [15]	The construction schedule management model of prefabricated building based on BIM-RFID technology is proposed	If a progress rework occurs, the workload of real-time dynamic adjustment is large
Altaf et al. [16]	The production planning and control system of prefabricated components based on BIM-RFID technology is proposed	The system is limited to the theoretical framework, and the improvement of actual production efficiency needs to be verified
Li et al. [34]	The RFID technology is used to track the construction components and improve the construction schedule	As a data acquisition carrier, RFID has not been well used in its functions. It mainly uses BIM technology to adjust the construction schedule
Rueppel [35]	An indoor emergency navigation system based on BIM-RFID is constructed	The positioning function of RFID technology is only used, which involves less information integration
Costin and Teizer [36]	The integration of BIM and RFID technologies improves the accuracy of indoor positioning	There is little research on the data integration of BIM and RFID
Lee et al. [37]	BIM and RFID technologies are used to manage the whole life cycle information of construction site materials	The collection and storage of material information is not comprehensive enough and information visualization is not formed
Yun et al. [38]	This study used BIM technology to simulate the construction process, which effectively improves the simulation results	It is only a preliminary study, and the use of RFID technology is not deep enough

In order to meet the application requirements of collaborative management of prefabricated building materials, the integration of BIM and RFID technologies involves both interface integration and system integration. In the interface integration part, the data of the component in the model and the prefabricated component state information collected by the RFID are extracted by calling the API in the Revit software to realize the interactive sharing of the two data, as shown in Figure 1.

In the system integration part, the RFID entity can be defined by IFC, a new RFID family can be constructed in the actual model, and the RFID tag location can be visualized in the BIM model to enhance the integrity of the combination of RFID and BIM. To customize a new IFC entity, the entity (Entity), type (Type), and its own properties (such as type enumeration (TypeEnum) and constraint (Where) attributes) should be added to its parent object. Modifying the EXPRESS file can be done manually or through the EXPRESS-G view (the EXPRESS-G view describes the inheritance relationship between the levels through the tree view) [32]. When the number of entities that need to be expanded is large, the manual modification step is cumbersome and error-prone. But the use of the EXPRESS-G view can greatly reduce cumbersome steps and reduce the error rate. Special EXPRESS conversion software (e.g., ExpressEngineTools) can be used in actually updating the IFC entity.

Taking the research object RfidSystem in this paper as an example, a new entity IfcRfidSystem can be added in the

electrical field (this entity does not exist in the predefined type of IFC4). First, the definition of the IfcRfidSystem entity name should be added to the EXPRESS file. Then, the definition of IfcRfidSystemType should be added to the IfcFlowTerminalType of the parent object. Finally, the custom entity IfcRfidSystem should be added in the EXPRESS file. The location of the IfcRfidSystem entity in the EXPRESS-G view is shown in Figure 2.

Since an RFID tag is placed on a prefabricated component, it can be assumed that the tag is an object itself. To model in IFC, each RFID tag needs to be assigned to the object it is tagged on by using IfcRelAssigns. For instance, if a rectangular column is tagged, then IfcRelAssignsToActor would be used since the tag relates to the defined properties of the rectangular column (name, type, floor, etc.). The RFID technology generates the real-time data. For each read, in which the read rate can be adjusted accordingly, the main data produced consist of the (a) RFID badge ID number, (b) timestamp, and (c) reader Internet protocol (IP) address, which can determine what zone the read is in. The RFID badge ID number data are linked with additional data about the tagged item by setting or defining properties using IfcPropertySet. Therefore, when a tag is read, all information about the prefabricated component will be available.

Based on the definition of the RFID entity by IFC in the foregoing, the RFID tag device can be added to the actual building model by means of a new family so that the position of the RFID tag can be visualized in the model, as shown in Figure 3. The newly built RFID family can be identified by

FIGURE 1: BIM and RFID data interface integration.

the BIM model so that managers can not only clearly see the status of RFID tags embedded in each component but also track the corresponding position of prefabricated components with RFID tags in real time.

According to the review, in order to solve the problem of information islands caused by the inconsistent data format between BIM and RFID systems, BIM can read RFID information through the ID mapping connection of MS database based on the secondary development of Revit in C# language and import the information collected by the RFID tag into the actual building model. In addition, in order to better manage the embedded RFID tags in concrete components, new RFID families can be built in the Revit model. Based on the accurate analysis of IFC data, this paper focuses on the core issues of BIM technology-based structural data transformation, BIM and RFID data integration, so as to provide solutions for BIM and RFID technology-based information collaborative management of prefabricated concrete components in prefabricated buildings. The data interface integration and system integration of BIM and RFID are mainly represented by the secondary development of the prefabricated component information extracted from the RFID information system and the physical model in Revit. The technical route is shown in Figure 4.

3.2. Concrete Prefabricated Component Information Inquiry. The operation mode of the RFID system is composed of two main components: an RFID tag (Tag) and an RFID reader

(Reader). Both parties use RF transmission technology to transmit data. When the RFID tag passes the effective range of an RFID reader, the RFID tag will transmit the information to the RFID reader. Then, the RFID reader combines with the information system to provide the function of information inquiry and item identification. Figure 5 is the RFID composition and workflow chart [9, 40]. The RFID tag code is unique, which can ensure the uniqueness of the code identification of each component unit and ensure the accurate information of each component in the process of production, transportation, and hoisting operation and maintenance, thus effectively solving the rework problem caused by confusion [41]. The function of the RFID system is achieved after the concrete prefabricated component being loaded with the tag enters the radiation range of the video signal emitted by the reader and activated tag. And then its encoded information is transmitted to the reader for processing analysis and translated into an identifiable effective by the background control center. The application information is transmitted to the BIM system for judgment and processing.

Before collecting information, the production personnel of prefabricated components should carry out some preparatory work, such as the processing of embedded parts, the processing of reserved holes, and the production and coding of RFID tags. Then the staff will make a qualified RFID tag placed on the prefabricated component, and the label recorded data information mainly include the name of the component number, manufacturer, raw materials, location,

FIGURE 2: IfcRfidSystem entity EXPRESS-G view.

FIGURE 3: RFID tag visualization.

detection time, and other aspects of data. Specific label information recorded steps are as follows: according to the production process of prefabricated entry label information by stages, namely, concrete before entry, inspection entry, product inspection phase input entry, and delivery stage, the main type of prefabricated product number, production date, and information such as product inspection records are input, and after the information input, they are uploaded to the server and the entry operation is completed. In case of unqualified inspection in the process of production in the

factory, unqualified data information is input in the supervision and inspection stage and is uploaded to the server, and then rework or scrap is carried out.

PC components entering the engineering site will quickly be identified by the radio frequency reader, and the component information contained in the radio frequency tag will be uploaded to the maintenance center by the field wireless network. The maintenance center accurately verifies the relevant information and imports it into the BIM model database for update. Finally, the management personnel

FIGURE 4: BIM-RFID data integration under IFC extension.

FIGURE 5: RFID device composition and workflow.

reasonably stores the PC components according to the real-time information in the BIM database and informs the construction unit of the data information of the components. In the intelligent management of information of prefabricated components, it is necessary to transmit the RFID tag information through the reader/writer and construct the information layer and BIM for information transmission as well as use the RFID tag information as an external database of the BIM database. The object-specific information (ID and other information) that needs to be monitored is added to the BIM database through programming or external software support. As the label is continuously scanned in the engineering project, the label information is continuously updated and transmitted with BIM [42]. It can visualize the functions of the physical location and physical attributes of the object to be monitored in real time and realize automatic storage of information to form a BIM external database.

The communication between the PC side (BIM) and the RFID device is established through the C# program, and the PC receives the tag ID from the RFID reader. This ID is used to perform a database query, and the query result is sent back to

the BIM model to display the result. This automatic information interaction system assists the user in accessing various component information and realizing automatic information flow interaction from real-world objects to BIM elements, as shown in Figure 6. In this process, the information flow is automated, improving efficiency and reducing human error. Among them, the communication between the readers, the tag, and the PC-end data, respectively, corresponds to query, retrieval, input, and output.

4. Case Study

This paper takes a single-family villa in Shanghai as the research object, preembeds the RFID tag on its concrete precast column, prefabricated beam, and other components, and writes the basic information of each component, such as component type, manufacturer, and date of manufacture. In the operation and maintenance management process, the temperature and humidity information of each component can be collected in real time through the RFID temperature and humidity label, which provides decision-making reference for the maintenance personnel to evaluate and maintain the quality of each component. Figure 7 shows the three-dimensional building model of the villa. The empirical process of this research consists mainly of RFID information collection and visualization of prefabricated component information in Revit 2018.

4.1. RFID Information Collection. RFID-based information collection is mainly through the selection of suitable RFID tags, antennas, readers, and other devices and connected to the PC for debugging and finally extracts the information required for each prefabricated component stored in the RFID tag.

- (i) RFID device selection: there are three main categories of RFID devices: passive, active, and semi-active. The active RFID device can be powered by using the battery inside the tag without the reader

FIGURE 6: BIM and RFID-based prefabricated component information viewing path.

providing energy to start. The tag of it can actively emit electromagnetic signals and the recognition distance is long, usually up to tens of meters or even hundreds of meters, and the stability is good. In this study, the active RFID device has an absolute advantage over other similar products, which can effectively read the information of the field components, and has a high reading rate. In addition, the anti-interference performance of the RFID device is superior which can avoid the omission of information reading in the process of embedding concrete components and improve the accuracy of reading and writing. The RFID devices selected in this paper are all active, as shown in Table 2.

- (ii) RFID equipment debugging: after the selection of RFID equipment and the preembedding of RFID tags, the work process can be debugged to achieve the best effect. The reader adopted in this paper is an active RFID equipment with long reading and writing distance, high literacy rate, and accuracy. Firstly, the reader is connected to the 220 V ac power supply, and PC port is connected to the reader with the prepared network cable and the serial port line of the device. Various parameters of the reader are started to be configured. Figure 8(a) shows the model C217001 active reader adopted in this paper, and Figure 8(b) shows the schematic picture of the connection between PC port and the reader during the experiment.
- (iii) RFID information extraction: after the RFID device is successfully debugged, the physical data of the smart tag that have been adjusted on the RFID reader can be read by the computer. In order to better import the information collected by the RFID

FIGURE 7: Case model.

system into the actual building model, the model ID of each component can also be written into the RFID tag to realize the unique correspondence of the tag ID. Table 3 shows the basic information of collecting and processing part of the concrete prefabricated components by RFID equipment.

4.2. Information Visualization. After the information read by the RFID tag is processed by the PC, the Revit 2018 can be redeveloped in the C# programming language, and the component information (Table 2) can be imported into the actual model. The three-dimensional information model of the building is used to realize the visual three-dimensional monitoring of the concrete prefabricated components, and the information data that each prefabricated component need to be monitored during the

TABLE 2: RFID device pick list.

Device type	Device name	Working frequency	Working range	Device advantages
C127001	Strip active label	2.4–2.5 GHZ	0–100 m	Small size, low power, without affecting the reading range, the battery life up to 4 years
C127003	Temperature sensor active label	2.45 GHZ	–50~150	Record label ID, time, and temperature. When the label reaches a certain temperature, an alarm is sounded
C217001	Adjustable gain active RFID reader	2.4–2.5 GHZ	0–100 m	Able to identify the label information of all directions within 100 meters and to fully identify and track the target
C326003B	UHF round polarized RFID antenna	902–928 MHZ	—	Multipurpose, high-process RFID antenna, mainly used for stationary UHF GNE2 RFID reader

(a)

(b)

FIGURE 8: (a) RFID reader and (b) PC port.

TABLE 3: Partial prefabricated component information read.

Component name	Type	Manufacturer	Factory time	Component ID
Rectangular column	300 * 200 mm	UB	2017/9/1	245582
	300 * 200 mm	UB	2017/9/1	245782
	300 * 200 mm	UB	2017/9/1	246735
	300 * 200 mm	UB	2017/9/1	245771
	300 * 200 mm	UB	2017/9/1	246207
	250 * 250 mm	UB	2017/9/8	245275
	250 * 250 mm	UB	2017/9/8	245168
Structural column	350 * 350 mm	UB	2017/9/28	242943
	350 * 350 mm	UB	2017/9/28	242817
	250 * 450 mm	UB	2017/9/28	240388
	250 * 450 mm	UB	2017/9/28	240627
Rectangular beam	200 * 400 mm	UB	2017/9/28	230382
	200 * 400 mm	UB	2017/9/28	303622
⋮	⋮	⋮	⋮	⋮
RFID ID	Floor location	Detection time	Temperature (°C)	Humidity (%)
5300000000005501	3F	2018/8/10 16:20	33.2	58
4600000000004070	3F	2018/8/10 16:20	33.5	58
5300000000005067	3F	2018/8/10 16:20	32.8	58
4600000000004607	3F	2018/8/10 16:20	31.4	58
4600000000004062	3F	2018/8/10 16:20	34.2	58
4600000000004069	2F	2018/8/15 9:10	27.6	62
4600000000004068	2F	2018/8/15 9:10	28.7	62
4600000000004063	1F	2018/8/20 10:30	25.6	55
5300000000005500	1F	2018/8/20 10:30	24.7	55
5300000000004064	–1F	2018/8/25 14:25	22.3	57
5300000000005503	–1F	2018/8/25 14:25	22.6	57
4600000000004065	1F	2018/8/30 15:00	25.3	63
5300000000005509	1F	2018/8/30 15:00	24.9	63
⋮	⋮	⋮	⋮	⋮

FIGURE 9: RFID information system.

FIGURE 10: Visualization of prefabricated component information.

management process are stored and recorded. The related information of prefabricated components can continuously be added in the BIM during the operation and maintenance phase. As shown in Figure 9, the manager can directly view the basic information of the prefabricated component to which the tag is attached by directly clicking on the developed RFID information system module and selecting the unique identification ID of the RFID tag to be viewed.

The currently imported RFID information mainly includes the basic information such as the name and type of the component, the manufacturer, and the date of manufacture. As shown in Figure 10, the administrator clicks on the specific RFID code such as 4600000000004070 to locate the rectangular column corresponding to the label. The specific location in the model, and the specific information of the component is displayed. The temperature sensor active tag can transmit the temperature and humidity data of the component in real time and can also provide an early warning in case of an emergency such as a fire.

5. Conclusion

With the promotion and practice of BIM technology, its application value is gradually expanded, which provides good technical support for the visualization and sustainability of information and can be used to solve problems such as the failure of timely query and correlation of data in the management of precast concrete components. In addition, by referring to the value of RFID technology in material real-time monitoring in recent years, its function of information storage and positioning can be better reflected in the prefabricated concrete building component management by relying on the BIM model. The main contributions of this study are as follows:

- (i) Based on the working environment architecture of BIM and RFID technologies, the IFC standard was used to build a new RFID family, and the C# language was used to connect the two databases, which realized the effective integration of the two engineering technologies, provided technical support for the information integration of prefabricated building components, and had important theoretical significance for promoting the informatization of project management.
- (ii) Through practical cases, the RFID information management module of prefabricated components was developed in Revit software, realizing the parameterization and visualization of prefabricated components' information and verifying the advantages of BIM-RFID technology in information update speed and information exchange accuracy.
- (iii) The application of BIM-RFID technology in prefabricated components' information management improves the problems of low manual recording efficiency, slow data exchange, and inconvenient information sharing in the traditional construction

site, makes the data acquisition mode change from manual to automatic operation, and realizes timely update and tracking feedback of component information state. It is of great practical significance for the on-site construction management of prefabricated buildings.

6. Limitation and Future Research Directions

This study only applies BIM and RFID technologies to the visual management of information of precast concrete components. How to make good use of these visualized prefabricated component data to provide support for construction management, operation, and maintenance management of prefabricated concrete buildings needs to be further studied. In addition, some enforcement limitations from government regulations for the control of wireless communications between RFID tags and reader are not fully considered in the study.

With the advent of the era of big data, RFID, as an information carrier, will be applied more and more widely in the field of architecture. How to collect more information of prefabricated components and promote the information collaboration between RFID and BIM is the author's future research direction.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Supplementary Materials

The supplementary materials mainly indicate the full names of the eleven acronyms involved in this study. (*Supplementary Materials*)

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