construction efficiency of prefabricated buildings (Qiu 2016). The loading sequence of components and the progress of the construction site are all in requirement of immediate communication. Confusions such as whether new components need to be transported or whether the lifting sequence of components needs to be updated still exist in the construction process.

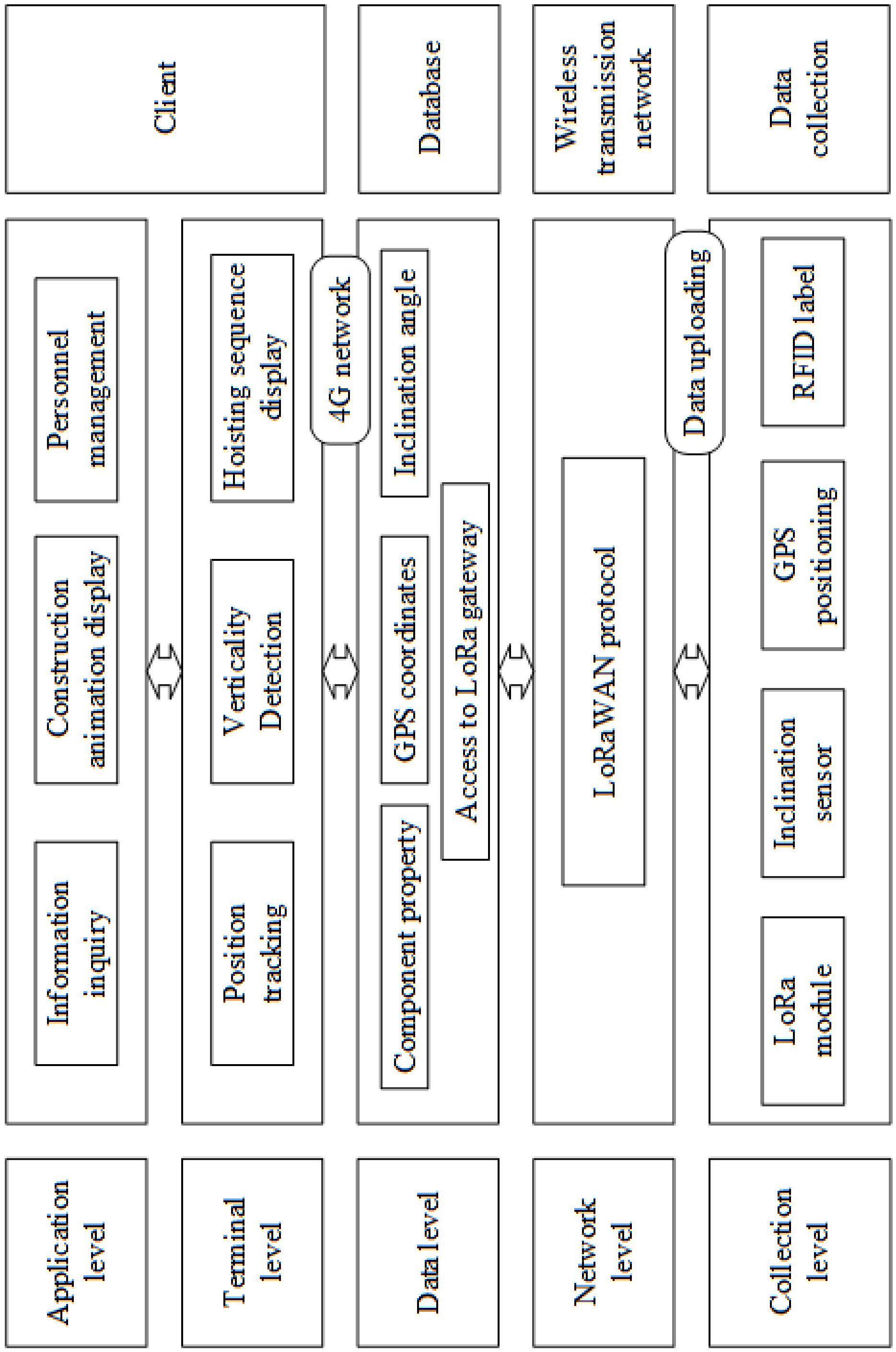


Figure 4. Functional architecture of LoRa system.

Component positioning and correction: When hoisting prefabricated components, the test hoisting is carried out first, and then the components are hoisted to the approximate position according to the pre-measured setting-out position. After the hoisting, it is crucial to correct the verticality detection component, which determines whether the reference line of subsequent component hoisting is correct. This process requires skilled cooperation of field workers and crane operators. There is no positioning equipment to control the real-time location information of the components when it is conducted traditionally. The data collected by RFID technology is static and needs to be matched to check whether the component information is wrong. It cannot conduct the intelligent monitoring of the real-time status of components during hoisting and installation. Because of the low degree of informatization and communication efficiency, the verticality detection method might cause hidden dangers to the safety of constructors, and affect the construction progress.

For the reasons given above, the industrialization form of prefabricated buildings is determined by its structural characteristics. Information collaboration is particularly important in the construction process. Traditional management mode cannot meet the demands anymore. Although significant improvement has taken place in component design and production (Yang and Jiao 2017), backwardness and imperfection in information and data management are still serious problems.

PLAN IMPLEMENTATION

Preparation: (1) Construction personnel. Before formal construction hoisting, construction personnel should be trained to use handheld devices, to read module data, and to guide visual construction in combination with BIM technology.

(2) Hoisting sequence. Before the construction of the project, all the detailed design information about the drawings needs to be entered in the BIM model. At the same time, the hoisting sequence should be reasonably arranged, and the corresponding charts need to be generated in advance to be inspected later by the construction personnel. The number of flat cars depends on the hoisting sequence.

(3) Components before entering the field. Passive RFID labels are installed in the four corners of components when they leave the factory. Property information of components, including type, material, and size, is recorded in labels. The information keeps changing throughout the whole construction process. The active label groove is also reserved on the component. When entering the field, the active transmission module is put into the groove to monitor the component information in the subsequent construction process.

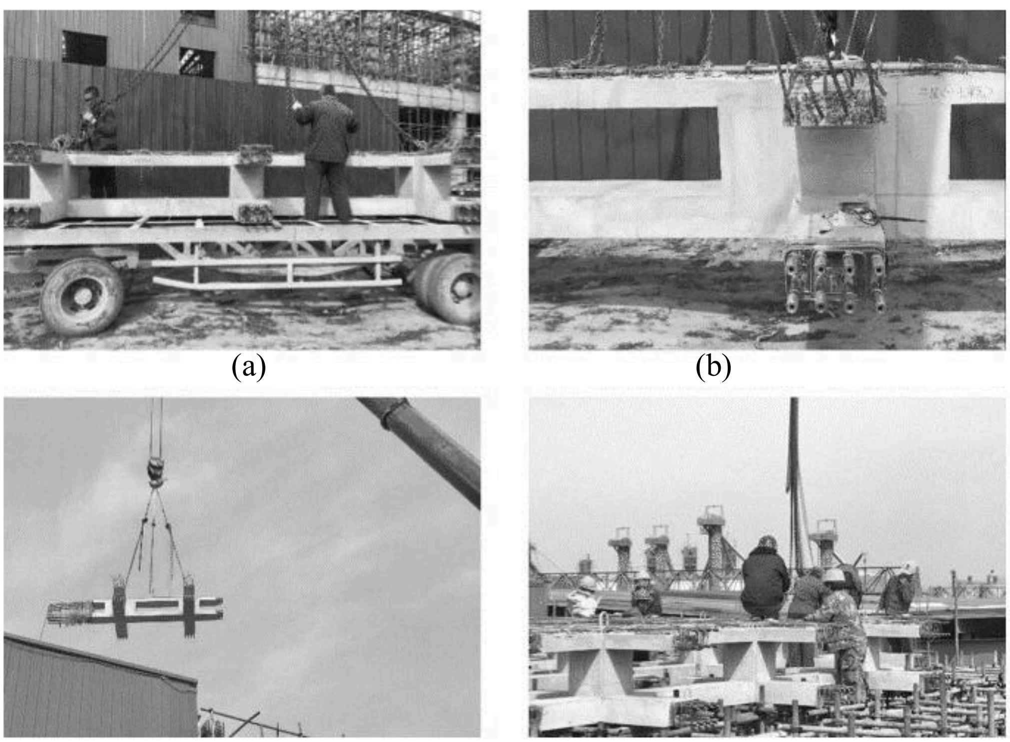
Information binding: The construction personnel can scan the RFID label on the component through RFID card reader. RFID labels contain the property information for each component, and whether the information is consistent with the model number and size of the binding component. After all the information is checked correctly, the active label locates the target component through GPS and transmits all the information to the cloud server through the transmission module. The data from both passive and active labels are then matched and bound in the cloud server.

Through this matching method, terminal devices update component information in real-time so the construction personnel can check the current status of the component at any time to prepare for the subsequent information call.

Component stacking: After the installation of the active positioning module and the collection of all component information, the trailer will transport the prefabricated components to the site for hoisting, and classify them according to the different parts. The construction workers can obtain an overview of the progress plan of the simulated construction through handheld devices. They can put the components in the most reasonable position according to the construction sequence and the degree of demand. Therefore, the constructors can arrange the transportation route better and prepare for the hoisting at construction site.

Hoisting process: After being informed about component requirements from the construction site, the active label is scanned by the RFID card reader to wake up the MCU it the IoT module, and control the transmission module to re-enter the working state, which results in activating the active label for real-time transmission of information. The constructors need to confirm the component information and check the hoisting sequence through the system, and ensure that the loading sequence is consistent with the hoisting sequence, avoiding secondary hoisting. Meanwhile, the handheld device displays detailed information about components. After confirming that the component information is correct, transport the components out of the storage yard and input the information that the components have entered the construction site for hoisting.

During the hoisting process, constructors can receive the information sent by the active label on the mobile flat panel to view the status and movement of the component in real-time and grasp the location information in real-time through GPS positioning. Meanwhile, they can also transfer the information to the cloud for backup to make subsequent calls and checks.



(a) (b)

(c) (d)

Figure 5. Hoisting process.

In addition, the system based on NB-IoT technology can realize the construction animation display of terminal BIM model. The BIM model is integrated into the system through IFC (Industry Foundation Class) data interface. Meanwhile, construction animation is imported. Through programming, the component being hoisting is highlighted in BIM model and its current construction stage can be seen with the construction animation display function and they can match the information with the BIM model at any time to avoid errors.

After the prefabricated component reaches the designated marking position, with the support of NB-IoT and LoRa module, the inclination sensor in the transmission module of active label will sense, obtain and then transmit the angle of the component to the gateway in real time through the module. After, the data will be saved to the ECS through 4G network, and judge whether the verticality meets the requirements in the ECS, avoiding manual error made by manual measurement such as the plumb line approach, etc.

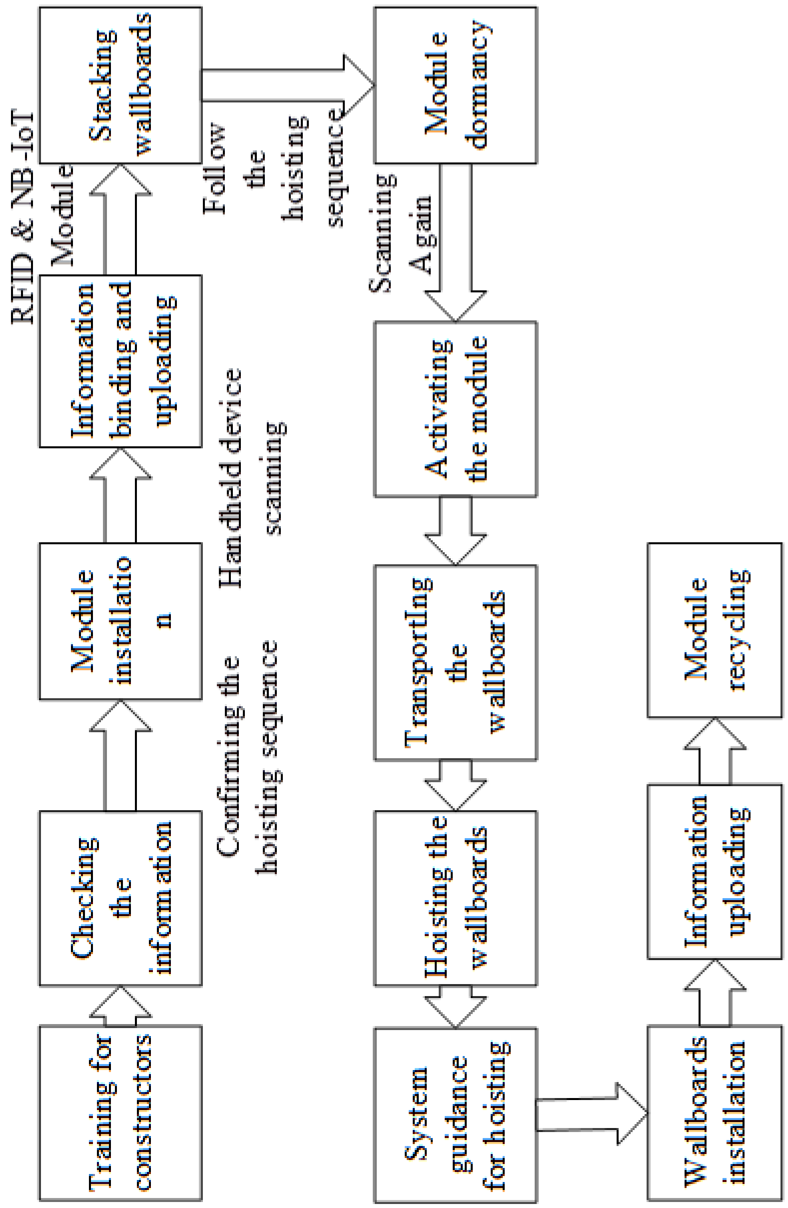


Figure 6. Flow chart of NB-IoT plan.

Components are towed to the site by trailer. Afterward, workers install hooks, fix modules on components with tape, and then hoist components to designated locations to complete the positioning monitoring of a component. The hoisting process is shown in Figure 5. (a) Hook

Installation; (b) Module Installation; (c) Component Hoisting Process; (d) Component Installation.

Information upload and label recycling: After the prefabricated component is installed, subsequent grouting treatment needs to be carried out. Key data such as flatness and verticality need to be checked. Constructors can get relevant information about whether the verticality of the components meets the requirements on the handheld terminal device. After confirmation, upload information pertinent to the database of the cloud server for subsequent inspection and verification. Afterward, dismantle the module, and the active label on the component is removed for recycling. In the final, reset the ID information for later hoisted components for reuse. In this way, the whole process of information monitoring from entry to the installation of a component is completed.

The system plans and corresponding processes of the two technologies are shown in Figure 6 and Figure 7, respectively.

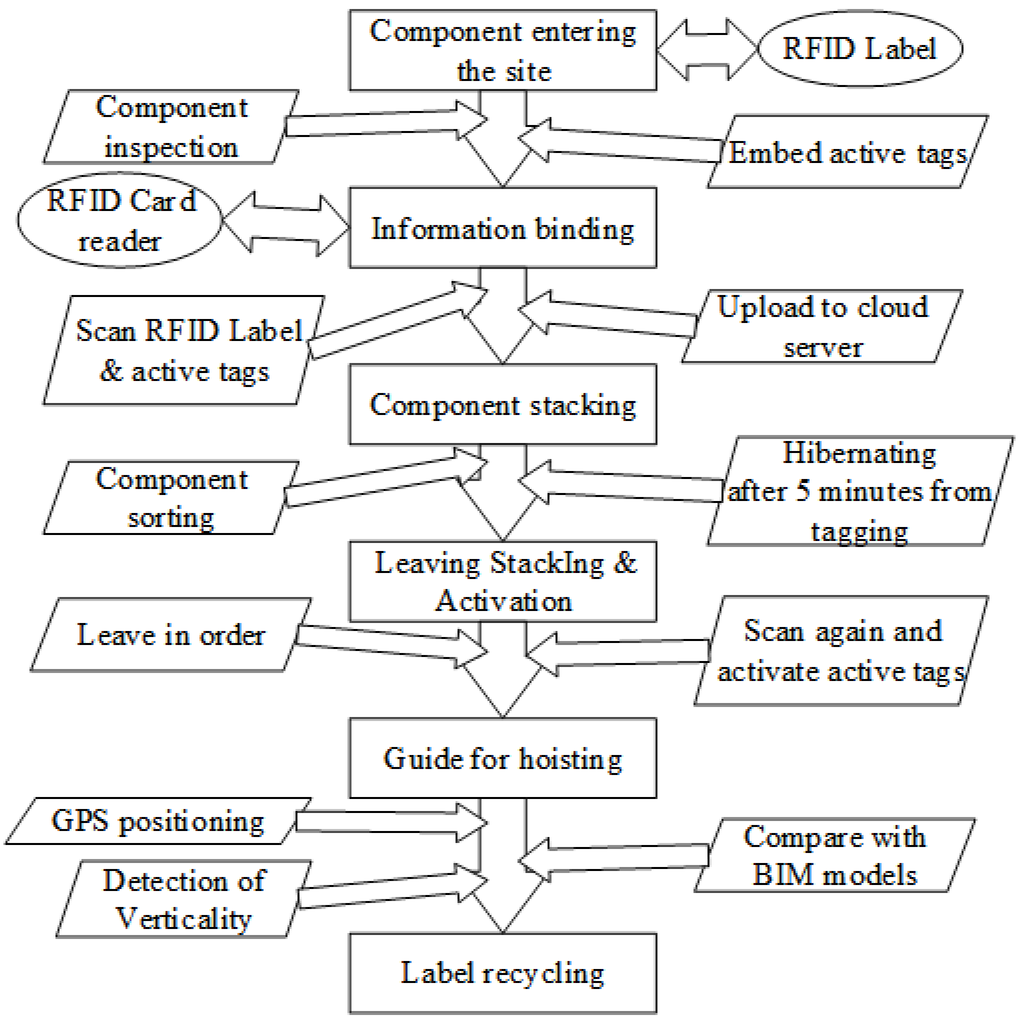


Figure 7. Flow chart of LoRa plan.

PLAN BENEFITS

Reduce the probability of making errors: Intelligent, visual management based on LoRa technology effectively avoids construction errors. Beidou GPS positioning module locates the prefabricated components at the meter level with accuracy. Besides, the module resubmits the information in real-time so that the commander can have the same information as the crane operator does, thus reducing the communication difficulty with field workers. The verticality information of components monitored by the inclination sensor also reduces the measurement error caused by manual measurement of workers, thereby reducing the construction error probability as a whole.

Improve construction efficiency: From the technical point of view, applying the communication mode based on NB-IoT technology in prefabricated component construction has made up for the shortcomings of small coverage, high power consumption, and poor penetration in the transmission process of traditional wireless network. The efficiency of communication has been improved between workers. IoT system based on LoRa technology traces the whole construction process of prefabricated components informationally, which simplifies and speeds up the process of information input, upload and feedback. Construction personnel, tower crane operator and management personnel can acquire real-time and consistent component information through mobile terminals, avoiding inaccuracy or misunderstanding in the information transmission process. Also, because of their low energy consumption, there is no need to replace module batteries throughout the whole construction cycle.

IoT technology enables managers to monitor multiple construction processes at one time. Numerous tasks can be coordinated and managed at the same time, leading to significant improvement in construction efficiency (Lei 2016).

Meet the development demands: The “13th Five-Year Plan” proposes to strengthen the application of information technology in prefabricated buildings. This paper proposes the application of LoRa and NB-IoT at the forefront of IoT technology to the construction of prefabricated buildings, which provides technical support for the construction site. In addition, the application innovates the prefabricated building construction management mode and means. By saving the cost of separate networking, commercial features have been used to apply the already established network directly, making the application more stable and safer. All in all, the foundation for further development of prefabricated building intelligence has been laid.

CONCLUSION

In an era of rapid development of science and technology, Internet of Things, as a technical carrier of industrial informatization and intellectualization, can bring great convenience to the industrialization of buildings. Applying NB-IoT and LoRa technology into the construction process of prefabricated buildings provides effective and intelligent means in terms of prefabricated components management.

This paper compares a low-cost, low-power modular intelligent sensor based on NB-IoT technology with a prefabricated building construction information solution based on LoRa wireless communication technology. Both of them meet the government’s requirements to establish a path of improving the information monitoring system for the quality of the project. They also satisfy the demands of informatization and refinement of the prefabricated building construction site. The applications of NB-IoT and LoRa technology provide technical support for the informatization and intellectualized management mode, making significant contribution to the transformation and upgrading of construction industry. The plan will be designed in a more refined way in the future, thus creating a scientific research foundation for the full realization of “Intelligent Construction”.

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Research on Restricting Factors and Countermeasures on the Promotion of Prefabricated Construction in China

Xueshan Sun[1] and Lipeng Wei[2]

[1]Lecturer, Dept. of Economic and Management, Zhonghuan Information College, Tianjin Univ. of Technology, Tianjin, China (corresponding author). E-mail: crystal171@live.cn
[2]Lecturer, Dept. of Economic and Management, Zhonghuan Information College, Tianjin Univ. of Technology, Tianjin, China. E-mail: lipengwei@tjzh.edu.cn

ABSTRACT

With the rapid development of construction industry in our country, the demand of the development of prefabricated construction is rising obviously. Prefabricated construction with the characteristics of green construction, high efficiency, and strong intensive, can improve the deficiencies in traditional construction greatly. It is fit for the future development of the construction industry. However, prefabricated construction in our country is not goes well. The key affecting factors on the development of prefabricated construction are analyzed in this paper. Then using the AHP analysis from four aspects of policy, technical, economic, and market to show the restricting factors of prefabricated construction's promotion and put forward some countermeasures to promote the development of prefabricated construction in our country.

INTRODUCTION

In recent years, with the expansion of domestic construction market, the traditional way of construction has been unable to meet the needs of the development in our country. The transformation and upgrading of construction way is imperative. At present, the traditional construction mainly on cast-in-situ construction and the model of long construction period, high pollution, labor intensive construction has a huge influence on the environment and resources of our country (Dai 2017). Therefore, the plight of resources, ecological environment problem and the "labor shortage" which all make the prefabricated construction become a mainstream trend of the construction market in the future. With the advantages of environmental protection and short time, prefabricated construction can largely promote new construction methods and the level of urban construction (Zhang and Li 2018).

For the technology of prefabricated construction, many foreign countries have already to promote and the remarkable achievements have been made. Germany is the world's first country to using prefabricated construction. Most of the prefabricated construction in Germany with the structure system of shear wall, concrete and composite plate, which can not only improve the efficiency of the construction, but also can increase the durability. In order to meet the requirements of domestic residents housing, Japan has developed the prefabricated construction. By 2018, prefabricated construction technology has been widely used in the market of Japan. In addition, the application range of French's prefabricated construction is very wide, which is most mature countries around the world.

The technology of prefabricated construction enters our country not long, but many related researches have been carried out by scholars. Shi and Kang (2016) put forward the key elements influencing the prefabricated construction cost by analysis the domestic construction industry situation. Among the influencing factors, the construction of tax cost, construction cost, the cost of production of components is an important component of the prefabricated construction cost.

The cost of production is one of the most important components. Li and Geng (2013) takes the concrete construction cases as the research object to analysis of the different ways of construction costs. Results show that compared with the traditional cast-in-situ construction, prefabricated construction capital cost is lower. In 2010, the characteristics of structural system of the CSI fabricated are introduced by Liu and Liu (2010). She proved that this kind of structure system can greatly reduce the waste of energy and can also promote rapid development of the prefabricated construction. Zhang (2014) analyzed the industrial prefabricated high-rise steel structure, main technology, standards and specifications based on the advanced theory of prefabricated construction.

As mentioned above, the abroad application in many countries have proved the advantage of prefabricated construction and many researches in our country also demonstrated the feasibility of prefabricated construction. But, the overall development situation of prefabricated construction is not optimistic in our country. Prefabricated construction has been applied for some cities, but the effect is not obvious and the applicable scope is very small.

THE DEFINITION AND SWOT ANALYSIS ON DEVELOPMENT OF PREFABRICATED CONSTRUCTION

Definition of prefabricated construction: Prefabricated construction refers to the building that based on the dry operation as the core and combines all modules together. Its raw materials are prefabricated parts and artifacts that have been put into industrial production. According to type of the building, it can be divided into modern wood structure construction, steel structure construction, PC construction and others (Jiao 2015).

Prefabricated constructions are characterized by “integration of five elements”. It refers to the use of BIM technology to improve the level of construction information management, adhere to the principle of reducing pollution, saving resources and efficiency to accelerate the integration process of construction, production and design (Shi 2016).

SWOT analysis on the promotion of prefabricated construction in China: As a new type of construction mode, prefabricated construction has its advantages compared with traditional construction mode. However, it needs to be further analyzed whether the prefabricated construction can adapt to the current market situation of China. To show the extensibility of expounds for prefabricated construction in China’s market, the SWOT analysis is carries out on them. The results are shown in Table 1.

Table 1. The SWOT Analysis of Prefabricated Construction Using.

Strength	Weakness	Opportunity	Threat
1.Policy 2.Economic 3.Technology	1.High cost 2.Unstandardized industry 3.The lack of industrial chain	1.Environmental requirements 2.Rising of labor costs	1.Market saturation 2.Low acceptance

It is not difficult to see from Table 1 that the development of prefabricated construction in China is a combination of opportunities and challenges. First of all, prefabricated construction as a new mode has been attached great importance by the state. And the state has successively issued some relevant documents to encourage the application of prefabricated construction in China. Therefore, its promotion process has policy advantages. In particular, in recent years, the state has gradually increased its attention to environmental protection. The traditional