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Application of BIM based information management technology in prefabricated buildings

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16 **ABSTRACT**

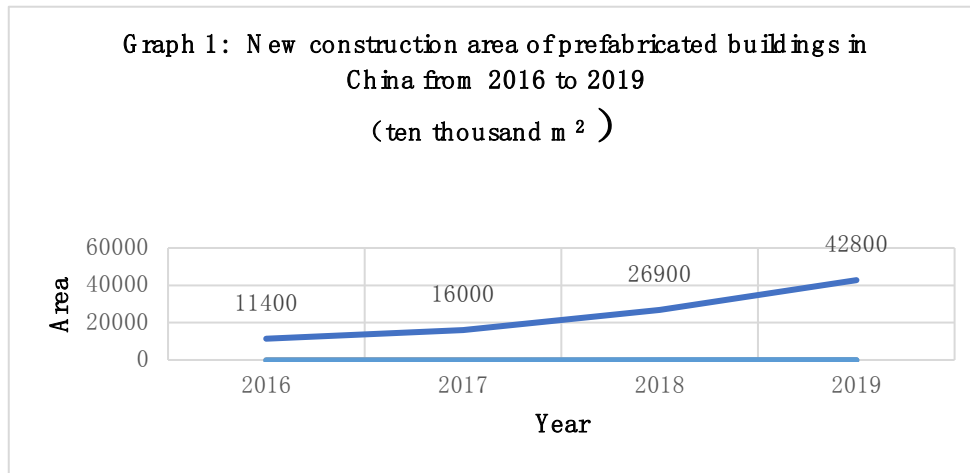
Under the background of industrial transformation and green development of construction industry, prefabricated building has become an important means to promote the development of construction industrialization and environmental protection. In the period of new and old construction mode change, the construction links of in-depth design, component production, component transportation and assembly construction are added to the prefabricated building, which has higher requirements for the unity of the whole process of the construction project. BIM platform can unify the information of the whole process and coordinate the management of the whole process of the project. This paper expounds the application of information management technology based on BIM in the three processes of in-depth design, component production and transportation management of prefabricated building. Through the analysis and comparison of actual cases, it is concluded that the prefabricated building combined with BIM Technology has more advantages than traditional construction in design, management, capital, environmental protection, etc.

18 *Keywords: Prefabricated building; information management; transportation management; BIM Technology*

20 **1. INTRODUCTION**

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23 The common building construction method in China is cast-in-place reinforced concrete. However, there are a lot of
24 problems to be solved in the traditional construction mode under the modern green development environment: a lot of
25 construction waste, long construction period, low production efficiency and the rising cost of construction site.

26
27 Under the background of industrial transformation of the construction industry, prefabricated construction has become a
28 new choice to upgrade the construction mode. According to incomplete statistics, China's provinces and cities have
29 issued more than 150 policy documents related to prefabricated construction, and all regions actively promote
30 prefabricated construction projects. In 2019, the newly started prefabricated building area in China will be 420 million m²,
31 an increase of 45% over 2018. On the whole, prefabricated building has a good development trend in China. Graph
32 1 shows the newly started areas of prefabricated buildings in China in recent four years[1] (Data in Graph 1 is derived from
33 the China Prefabricated Building Development Report).
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Some domestic scholars have studied and analyzed the feasibility of BIM application in prefabricated buildings. Zhang Hao [2] proposed that the QR code identification generated by BIM model can be bound to the prefabricated components, and the information about the production, transportation and installation of prefabricated components can be queried and mastered through the code scanning form of intelligent devices, thus realizing an efficient management mode. Wei Dong quan [3] thinks that the application of BIM information model in assembly component processing and production can meet the needs of enterprise management, improve enterprise production efficiency and reduce enterprise operation cost. Chen Min [4] believe that the BIM based prefabricated construction project management improves the efficiency of project management to a great extent, and realizes the comprehensive information management in the aspects of component deepening, transportation management, quality inspection, whole process control, etc.

In this paper, the actual prefabricated building as a case, BIM platform as the carrier, to analyze the prefabricated building under the BIM management support of the construction mode. Using the way of data listing to show the advantages of the construction and production of prefabricated buildings; Taking the traditional construction as the object of comparison and using the method of data comparison, this paper demonstrates the advantages of prefabricated building in the aspects of labor, environmental protection and time, etc. Finally, according to the unique attributes of prefabricated building, it analyzes the difficulties existing in prefabricated building projects and puts forward relative solutions.

2. ANALYZE THE PROCESS OF DATA GENERATION OF PREFABRICATED BUILDINGS

Compared with traditional buildings, prefabricated buildings add more links in the project process, which makes the project operation and management more complicated. The construction process of prefabricated buildings is a chain process, which is connected with each other. A more systematic management mode is needed to make each link more precise. However, each link will produce a large amount of information and data, which need to be transmitted and exchanged by all parties.

There are differences in project process between traditional construction and prefabricated building, which produce a lot of data. The data generation stage in the new links of prefabricated building includes design stage, component deepening stage, component production stage, component transportation stage and component hoisting stage. The above added links involve the exchange, transmission and extraction of information, and the traditional construction technology is difficult to manage the generation of a large number of new information. Based on the theory of BIM intelligent construction site, the information is managed by means of Internet of things and big data, and the management mode of assembly information model is established [5].

Sections 3, 4 and 5 will explain how prefabricated buildings generate data at the design stage, deepening stage and transportation stage, and how to use the BIM platform to apply it.

3. APPLICATION OF BIM TECHNOLOGY IN ASSEMBLY PROJECT

BIM is a platform based on the whole life cycle of the project, which should be lean designed according to the characteristics of prefabricated buildings to improve management efficiency. I selected a representative case in many BIM projects which designed by my company. This representative case is Nantong Party school.

3.1 Project overview

81
82 Nantong is a coastal city in Jiangsu Province, China. The project is Nantong Party school, which adopts BIM management
83 platform and assembly technology. The background of the project, Teaching building: 5 floors (height: 22.05m),
84 Administration building: 3 floors (height: 13.50m) and Auditorium: 2 floors (height: 17.45m), Canteen and Student
85 apartment building: 15 floors (height: 54.950m). The building structure is prefabricated integral frame cast-in-place shear
86 wall structure. The type of prefabricated components: precast beam, precast slab and precast beam. The assembly rate is
87 51% (assembly rate means the volume ratio of the amount of precast concrete in the main structure to the total amount of
88 concrete in the corresponding component).

89
90 Among these building, the student apartment building and teaching building are in the form of prefabricated building, and
91 the building structure is in the form of prefabricated integral frame cast-in-place shear wall structure. Table 1 shows the
92 prefabrication scope of prefabricated buildings. The BM modeling software used in this project includes Autodesk Revit
93 2018, Autodesk CAD 2018, Guanglianda gtj 2018, Tekla; BIM review software is Autodesk NavisWorks; BIM project
94 management platform includes Luban view v4.0.0. The total construction time of the project is 13 months.

95
96 As the structural engineer of the project, I am responsible for the prefabricated architectural design of the project. The
97 data of this project is obtained from the data manager, project manager and BIM engineering manager.

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100 **Table 1. Prefabricated building prefabrication scope**

Prefabrication scope	Student apartment building	Teaching building
Precast slab	2F-15F	2F-5F
Precast beam	2F-15F	2F-5F
Precast column	5F-15F	2F-5F

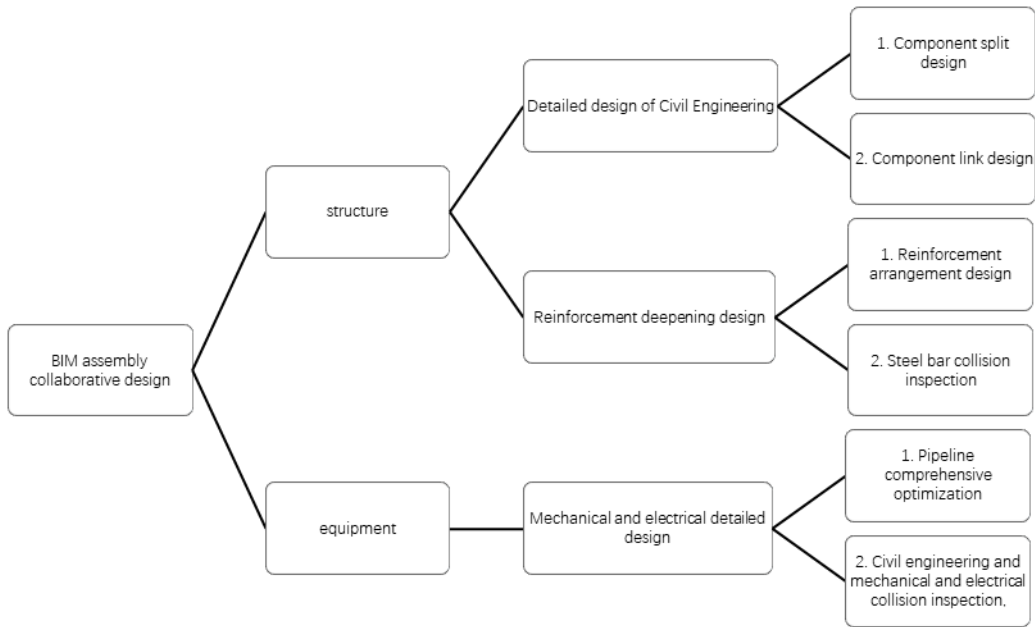
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102 **3.2 Application of BIM Technology in the design stage of prefabricated building**

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104 As the assembly project will encounter many problems, such as many specialties, short project cycle, and many technical
105 difficulties, this project designs a method of assembly collaborative workflow based on BIM platform, which can achieve
106 the whole process management of the project while coordinating various specialties.

107
108 Designers of different specialties can design and modify synchronously in a multi-user way. Under the condition of
109 collaborative design, conflicts between specialties can be found in time.

110
111 This project innovatively uses the synchronous modeling design method of structural engineer and equipment engineer,
112 which can not only save design time, but also find the problems between different specialties in the process of
113 collaborative design. It avoids the phenomenon that the problem is found and solved later in the traditional design.

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115 After the design of the main structure and equipment pipeline is completed, the assembly department immediately carries
116 out the component deepening work. The deepening work is divided into two parts, one is the arrangement of
117 reinforcement, the other is the reservation of wire box and hole for equipment pipeline on prefabricated components. The
118 specific design process is shown in Figure 1.



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Fig 1. BIM assembly collaborative design

Yuan who is the BIM engineer designs the initial model of the building and structure of the student apartment building through Revit. Figures 2 and 3 show the effect of the 3D model by Revit model.



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Fig 2. Architecture model

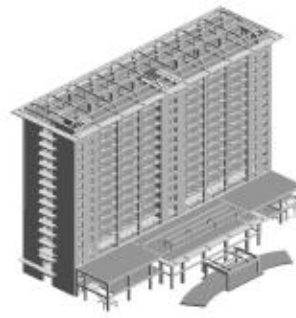
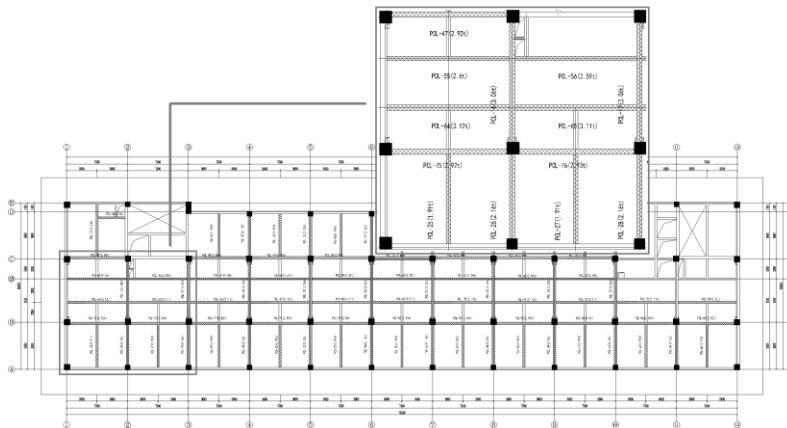


Fig 3. Structure model

130 The BIM structure model is used to split the prefabricated components. Structural engineers split the prefabricated
131 components of student apartment building by revit. The types of components are precast slab and precast beam. Figures
132 4 and 5 are CAD drawings which exported by Revit. Figures 4 and 5 below are the completed split drawing of precast
133 beam and precast slab on the second floor of student apartment building.
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Fig 4. Splitting of precast beam

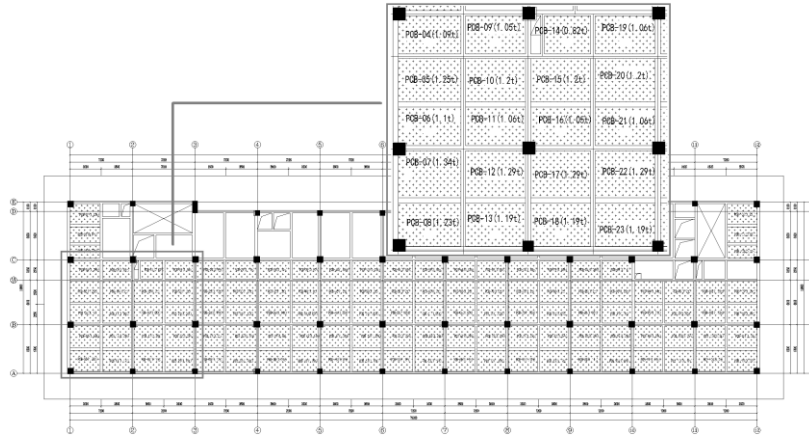


Fig 5. Splitting of Precast slab

The structural engineers use the common characteristics of IFC file format to import the IFC file of structural model in Revit into Tekla. In Tekla software, the nodes are used to arrange the reinforcement in the structural model, and the collision checking function of the software is used to adjust the position of the steel bars in collision, and the prefabricated columns, beams and slabs are combined in the model to avoid the steel bar collision of different components, so as to solve the problem of steel bar collision in the construction site (Fig.6)

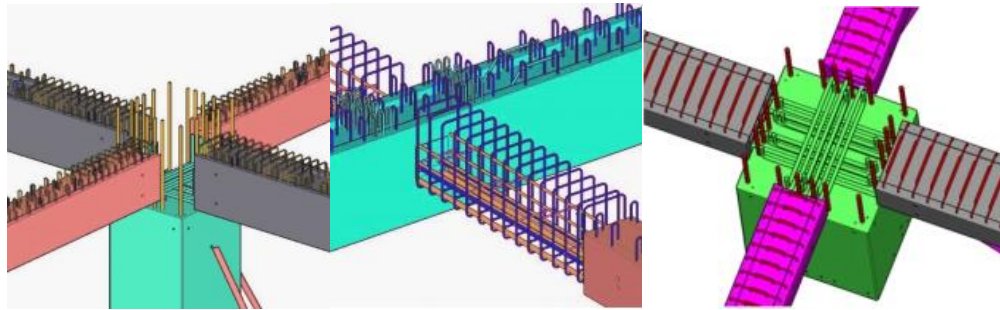


Fig 6. Steel bar collision adjustment

The first mock exam is to build the building, structure and equipment in the same model. The electromechanical equipment can be used as a three-dimensional reference for this model. The electromechanical equipment (Fig.7) is built in the BIM building model, which provides convenience for the electromechanical inspection in the hidden parts of the operation and maintenance in the later stage.

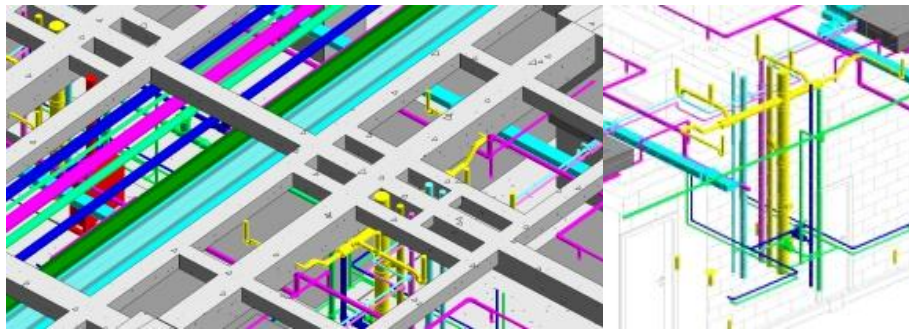


Fig 7. Electrical model

Revit can generate QR code of prefabricated components at the same time. Figure 8 shows Each QR code contains the data information of the components. Through the drawing function of the Revit, the detailed drawing of each component is designed. The detailed drawing includes the size information of the component and the number of reinforcement, and the data is integrated into the QR code (Fig.9)

The construction site can also query the original information of the component through the QR code generated by the prefabricated component in the BIM structure model, so as to confirm the specific location of the component, and also check the component size and reinforcement information. The component processing factory obtains the detailed

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information of the component through the QR code on the detail drawing, so as to carry out the production of the component.

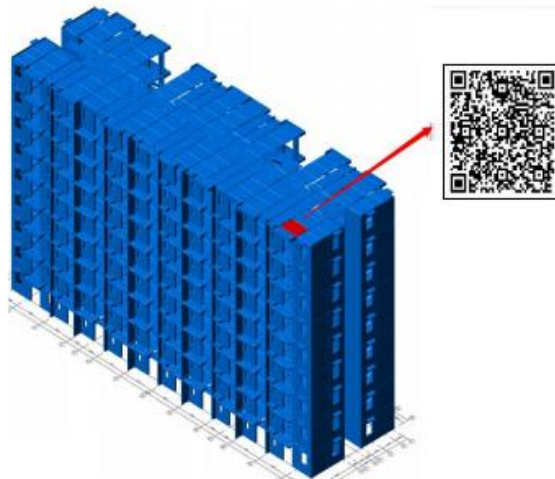


Fig 8. QR code of prefabricated components

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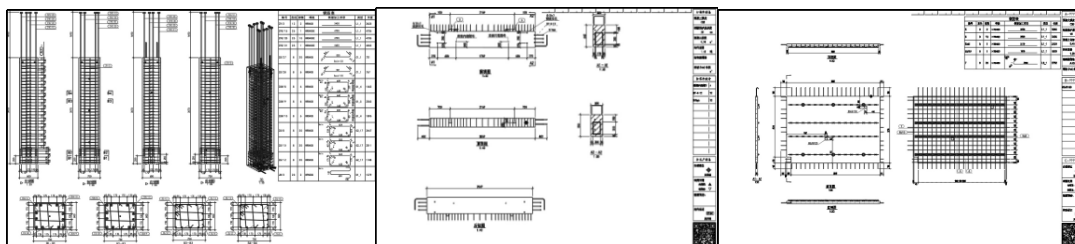


Fig 9. Detail of prefabricated components

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4. BIM TECHNOLOGY IS USED FOR INFORMATION STANDARDIZATION PROCESSING OF FABRICATED COMPONENTS

The material list of components is derived by Tekla software. The material list includes the number, size, concrete weight and reinforcement weight of components. The data exported by the software can first be provided to the component processing factory to make the mold. Secondly, BIM software was used to build assembly standard library. Each component is parameterized to form a standardized component information database. For production management and construction management. (Take the prefabricated components on the second floor of student apartment building as an example, some statistical data of precast beams, precast slabs and precast columns are listed (Table.2,3and4). Table 2.3and4 are also applied in the comparison of precast and cast-in-place in Section 5.

Table 2. Precast beam database

Precast beam									
type	Component size (mm)			Concrete quantity (m ³)	Bulk density (t/m ³)	weight (t)	number	Total amount of concrete	
	length	width	height					(m ³)	
PCL-01	250	460	6520	0.7498	2.5	1.8745	2	1.50	
PCL-02	250	460	3120	0.3588	2.5	0.897	4	1.44	
PCL-03	400	700	5970	1.6716	2.5	4.179	1	1.67	
PCL-04	400	700	5920	1.6576	2.5	4.144	1	1.66	
PCL-05	400	700	6070	1.6996	2.5	4.249	1	1.70	
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Table 3. Precast slab database

Precast slab

type	Component size (mm)			Concrete quantity (m ³)	Bulk density (t/m ³)	weight (t)	number	Total amount of concrete (m ³)
	length	width	height					
PCB-01	5020	2920	60	0.88	2.5	2.20	2	1.76
PCB-02	2920	1470	60	0.26	2.5	0.64	2	0.52
PCB-03	3370	1870	60	0.38	2.5	0.95	1	0.38
PCB-04	3120	1570	60	0.29	2.5	0.73	2	0.59
PCB-05	3145	1570	60	0.30	2.5	0.74	8	2.37
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Table 4. Precast column database

Precast column								
type	Component size (mm)			Concrete quantity (m ³)	Bulk density (t/m ³)	weight (t)	number	Total amount of concrete (m ³)
	length	width	height					
PCZ-01	800	1000	3680	2.94	2.50	7.36	1	2.94
PCZ-02	800	1000	3680	2.94	2.50	7.36	3	8.83
PCZ-03	700	700	3680	1.80	2.50	4.51	11	19.84
PCZ-04	800	800	3680	2.36	2.50	5.89	1	2.36
.....

From the above data, it can be seen that the fabricated component is a regular product, and the size, reinforcement and weight can be modularized. The reuse rate of the same mold in this project is up to 30%, which greatly saves the cost. Prefabricated components usually adopt the design concept of "more combinations, less specifications", which can reduce the production cost of the factory, improve the production efficiency of components, and reduce the assembly time on the construction site. The idea that I design prefabricated architecture is to divide the traditional concrete structure into individual parts. Then, these "parts" are processed in advance in the factory, and then transported to the construction site. Under the same construction concept of cast-in-place, the single structural components will be assembled together by the method of combined connection. After the company's design department completes the construction drawings of the project, the deepening department carries out the deepening design of the building structure. The common floor, beam, column, stair and wallboard are split according to the industry standard; secondly, the optimal scheme of steel bar will be considered. Therefore, a large amount of component data, which is different from the traditional design, would be produced in the process of component splitting. Therefore, the standardization of components is an important factor in the information management of prefabricated buildings

Traditional design usually shows the relationship between building location and elevation through construction drawings, which is an "integration" of information. However, prefabricated components decompose this "integration" of information and produce a lot of secondary information. If the splitting method is "personalized", it is bound to cause a lot of difficulties to the subsequent process sequence. Therefore, the standardization of component information is an inevitable requirement in the early stage of prefabricated building information management.

5. APPLICATION OF BIM TECHNOLOGY IN INSTALLATION OF PREFABRICATED BUILDINGS

In the design phase, each component will have its own unique "identity" information after splitting. By scanning the QR code bound on the prefabricated components with intelligent devices, the transportation situation of prefabricated components can be mastered. Through the combination of RFID^[6](radio frequency identification) technology and BIM information data model, the prefabricated components can quickly find the road matching with the size of prefabricated components on the network map, calculate the optimal route, and simulate the most suitable site location for component placement on the construction site through BIM model. Figure 10 shows the situation of RFID chips embedded in prefabricated components.



Fig 10. RFID chip is embedded in the component

RFID chip can be used to manage the quantity of prefabricated components produced by component factories. During the site hoisting process of prefabricated columns, the RFID chip can transmit the location information of the components to the BIM platform, and the management personnel can detect whether the installation position of the prefabricated components is accurate, and the site construction personnel can detect whether the installation of the prefabricated components is in place through the RFID chip. The flow chart (Fig 11) shows workers using RFID to guide the installation of prefabricated columns.



Fig 11. RFID application flow chart

248 **6. COMPARATIVE ANALYSIS OF PREFABRICATED BUILDINGS AND TRADITIONAL PROJECTS BASED**
 249 **ON BIM PLATFORM**

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 251 As a new form of construction, prefabricated building is not mature in many aspects, such as the high cost of
 252 prefabricated components, the lack of on-site professional prefabricated construction personnel, and the difficulty of
 253 assembly construction quality inspection and control. Now the prefabricated project is compared with the traditional
 254 project. The prefabricated project adopts the canteen and student apartment building of the project; **The traditional**
 255 **residential building is also located in Nantong, China, so as to reduce the regional differences. The traditional residential**
 256 **building has a total of 15 floors, and the total building area is about 8064m².**

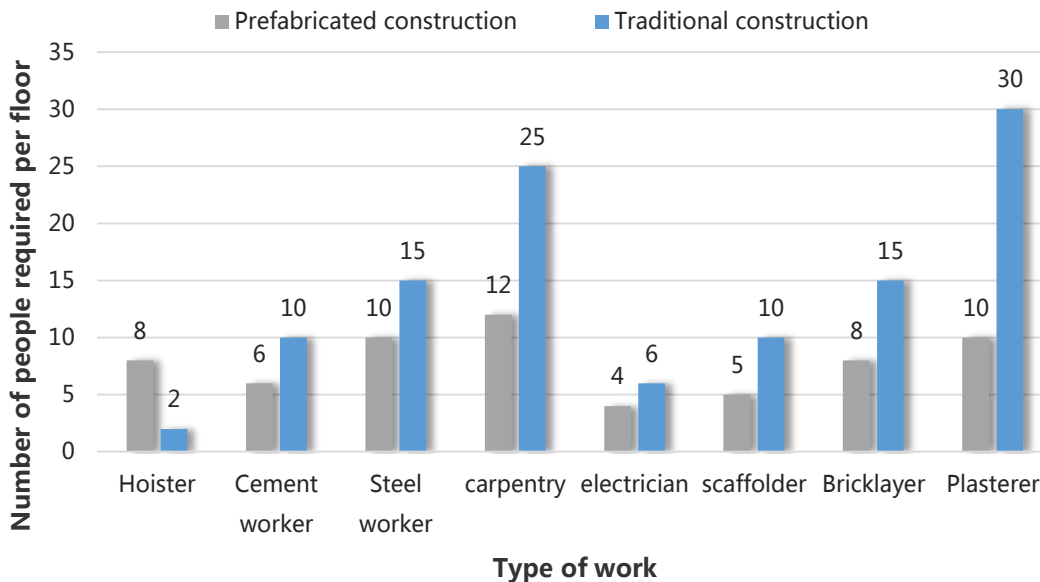
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 258 The comparison of labor index between prefabricated construction engineering and traditional engineering includes lifting
 259 worker, cement worker, steel worker, carpenter, water electrician, scaffolder, masonry worker and plasterer. Young
 260 people are reluctant to go to the construction site because of the aging of workers. Site employment has become an
 261 urgent problem to be solved at the construction site. Therefore, the amount of labor can reflect the differences between
 262 prefabricated buildings and traditional buildings. **BIM based assembly labor statistics is generated by BIM information**
 263 **management system and daily recorded data, while traditional construction labor statistics is generated by production**
 264 **recorder on construction site.** The comparison results are shown in Graph 2.

265 **Table 5.Index description of Labor volume**

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Type of work	duty
Hoister	workers for lifting prefabricated components
Cement	workers who cement the cast-in-place parts
Steel worker	workers who arrange steel bars
Carpentry	workers who make wooden moulds
electrician	workers who arrange hydropower pipeline
scaffolder	Scaffolding workers
bricklayer	Workers who masonry brick
plasterer	Workers who plastering the building

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 Graph 3. Comparison of labor consumption between prefabricated construction and traditional construction



269 **Graph 2.Comparison of labor consumption between prefabricated construction and traditional construction**

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 271 Through the comparison of the above indicators, it is found that the labor amount of prefabricated construction workers is
 272 only higher than that of traditional construction in terms of personnel hoisting, and other indicators are lower than that of
 273 traditional construction.
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Table 6 and table 7 show the comparison between prefabricated building and traditional building engineering in terms of project single index and cost data (The project data comes from the data statistics of the project cost software which is Guanglianda,china). Through the comparison in the above table, it can be seen that compared with traditional buildings, the consumption of steel and concrete in prefabricated buildings is higher, and other indicators are lower. The cost of prefabricated buildings is 15.8% higher than that of traditional buildings.

Table 6. Comparison of single index between prefabricated construction engineering and traditional construction engineering

Serial number	Entry name	Unit	Prefabricated building	Traditional architecture	compared with traditional buildings	Index calculation method
1	Concrete index	m ³ /m ²	0.41	0.39	+5.1%	Volume divided by area
1.1	PC component Concrete	m ³ /m ²	0.19	0		
1.2	Cast in place component concrete	m ³ /m ²	0.22	0.39		
2	Reinforcement index	kg/m ²	45.5	43.78	+3.9%	Weight divided by area
2.1	PC component reinforcement	kg/m ²	21.5	0		
2.2	Cast in place component reinforcement	kg/m ²	23.98	43.78		
3	Brick masonry	m ³ /m ²	0.04	0.15	-73.3%	Volume divided by area
4	Internal wall plastering index	m ² /m ²	0.38	1.99	-80.9%	/
5	Ceiling plastering	m ² /m ²	0.48	0.65	-26.1%	/
6	Template	m ² /m ²	2.09	3.65	-74.6%	/
7	Exterior wall painting base	m ² /m ²	0.81	1.65	-50.9%	/
8	Tower	One day's work/m ²	0.03	0.03	/	/

Table 7. Comparison of cost data between prefabricated building and traditional building engineering

Serial number	Entry name	Unit	Prefabricated building	Traditional architecture	Serial number
1	building structure	rmb/m ²	2915.85	2518	397.85
1.1	Assembly part price	rmb/m ²	300	/	/
1.2	Cast in place part price	rmb/m ²	2615.85	2518	/

In the national code for design of concrete structures(Technical specification for concrete structures of tall building,JGJ3-2010,china), the design standards for prefabricated structures are designed on the high side, so the amount of concrete and steel will be more than that of traditional buildings. At present, prefabricated building has not yet been popularized. The cost of prefabricated component mold is high, the unit price of component is high, the cost of personnel training is high, and compared with traditional design, the cost of prefabricated building will be higher than traditional building.

Using BIM model, the project information is integrated into a model. Through standardized design, the project can call these information in each stage, reduce the loss caused by trivial information, improve the utilization rate of information, and realize multi professional collaborative work. It provides an intuitive model for later construction and maintenance, and reduces the cost of later construction. Through the information model platform, the information of prefabricated components is integrated, and the reasonable component production plan is made to reduce the loss caused by human factors. Increase the reuse rate of preform mold and reduce the production cost. According to the national policy, in response to the call of the government, we should increase the scientific research investment in BIM and prefabricated building, and carry out research and development

The use of prefabricated buildings is also of great help in environmental protection. Through the detection instruments placed at the construction site, the pollutant emission at the construction site is recorded every day and recorded in a comparison table. Prefabricated building effectively reduces the content of PM2.5 and greatly improves the environmental quality. Table 8 shows the great environmental advantages of prefabricated buildings.

Table 8. Comparison of dust emission records

Serial number	Entry name	Unit	Prefabricated building	Traditional architecture	Serial number
1	PM index	$\mu\text{g}/\text{m}^3$	35	60	25
2	Sound level	Decibels	25	45	20
3	PH index	mol·L	PH<7	PH>7	/

*PM index: Monitor the concentration of dust or floating dust in the ambient air with an equivalent diameter of 10 μM ,

*Sound level: In order to protect people's hearing and health, and to ensure that people's living and working environment is not disturbed by noise

*PH index: The concrete measure to judge the degree of water pollution

7. CONCLUSION

Through the comparison of the above two actual cases, prefabricated building is 5.1% higher than traditional building in concrete usage and 3.9% higher in steel usage, which makes prefabricated building much higher than traditional building in cost. On the other hand, prefabricated building also has many advantages. Thanks to the new construction method, the labor consumption of prefabricated building is 35% less than that of traditional building, and the completion time is also earlier than that of traditional construction. In terms of environmental protection, the advantages of prefabricated buildings in air environmental protection, noise pollution and water pollution are far beyond the traditional buildings. The overall completion time of prefabricated buildings has also been advanced. It is proved that the prefabricated building based on BIM information management has the advantages of efficient management, green environmental protection and common data. Most of the literature at home and abroad is based on the one-sided demonstration of prefabricated building. The two practical engineering cases of prefabricated building and traditional building in this paper make a more intuitive comparison of the advantages of prefabricated building in the future construction industry. Next, in accordance with the national policy and in response to the call of the government, I will increase the scientific research investment in Bim and prefabricated buildings, and research and develop more energy-saving and material saving construction methods. Vigorously promote the prefabricated building, make the prefabricated building market more mature, so as to reduce the market price, promote the competitiveness of the prefabricated building market, and improve the popularity of the prefabricated building. It is of great help to the future development of the construction industry. The results can be used as a reference for related projects and make clear the idea of prefabricated building development.

8. DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors

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