

Research Article

Building Information Modeling Assisted Carbon Emission Impact Assessment of Prefabricated Residential Buildings in the Design Phase: Case Study of a Chinese Building

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The construction industry is energy-intensive and labor-intensive, which has great potential in reducing energy demand and carbon emissions. The construction method of off-site prefabricated components has many advantages to make it a good substitute for traditional methods. The purpose of this paper is to reduce the carbon emissions of prefabricated residential concrete members by improving the standardization rate of prefabricated components in the architectural design stage. In addition, this paper also uses building information modeling technology to establish Revit models and develops Revit using C# language to achieve rapid calculation of the prefabrication rate of building and standardization rate of components. The calculation results of the case show that, in the design stage, the carbon emissions are reduced by 2034.16 kg CO₂e by improving the standardization rate of prefabricated components, accounting for 0.1552% of the carbon emissions of all prefabricated components. This study can help the designer reduce the carbon emissions of prefabricated components, and this technology may make a significant contribution in improving the environmental sustainability of prefabricated buildings.

1. Introduction

Climate change is one of the most urgent challenges facing mankind today, and it is clearly related to greenhouse gas emissions [1, 2]. In recent years, the problem of air pollution in China was particularly prominent, and one of the most important problems was the emission of greenhouse gases. At present, China has become the world's largest emitter of greenhouse gases, accounting for about 21% of the total global emissions. China has solved this problem by raising public awareness and formulating new relevant standards and policies [3].

According to the statistics of intergovernmental panel on climate change, the construction industry consumes nearly 40% of the global energy and emits 36% of greenhouse gases [4]. Construction industry is one of the pillar industries in China, which produces a lot of greenhouse gases in the process of production and construction. According to the

national statistical data, steel consumption and cement consumption in China's residential construction account for 20% and 17.6% of the national total, respectively, 30% of urban built-up areas are used for residential construction, and 32% of urban water resources are consumed in residential buildings [5]. Therefore, it is one of the key ways to reduce greenhouse gas emissions in China's construction industry to carry out quantitative evaluation of carbon emissions of prefabricated residential buildings (PRBs).

In order to solve the contradiction between energy shortage and environmental pollution and break through the development bottleneck of extensive management and labor-intensive in construction industry, China has started to promote the development mode of prefabricated buildings since the 1990s [2]. Prefabricated buildings are mostly PRBs. Compared with traditional residential buildings, the construction process of PRBs has obvious advantages in energy saving, greenhouse gas emission, and ecological environment

protection [6, 7]. In [8], the greenhouse gas emissions of two residential projects with prefabricated and traditional construction methods were compared, and the results showed that compared with prefabricated projects, the greenhouse gas emissions of traditional construction projects increase by about 1.1 t per 100 m². In [9], they calculated the greenhouse gas emissions of prefabricated and traditional construction methods with the method of life cycle assessment and found that prefabricated methods can reduce the greenhouse gas emissions per cubic meter of concrete by 10%. In [10], they compared the environmental impacts of PRBs and traditional residential buildings based on ecosystem destruction, resource consumption, and health damage, and the results showed that the PRBs have higher energy efficiency and better environmental impact, with the ecosystem destruction reduced by 3.47%, resource consumption reduced by 35.82%, and health damage reduced by 6.61%.

With the popularization of the construction method of off-site prefabricated components, more and more researches have been made on carbon assessment of PRBs [2, 10]. In [11], they indicated that considering reuse of prefabricated components in the design stage can effectively reduce greenhouse gas emissions caused by construction waste landfill. In [12], they put forward a simplified calculation method of residential carbon emission, which can calculate the building materials with the largest carbon emission in the design stage and improve the efficiency of building design. In [13], the life cycle energy consumption of prefabricated building components and its influence on the total building energy consumption were studied, and the results showed that the average increment of energy use is linearly related to the prefabrication rate of building. Therefore, the prefabricated rate had important practical value for measuring the carbon emission of PRBs. However, the evaluation of carbon emissions of PRBs seldom considered the influence of prefabricated components optimization [14].

The meaning of PRBs is to build residential buildings using industrial production method, improve production efficiency, and reduce costs and emissions [3]. With the development of PRB technology, building industrialization has been regarded as a countermeasure to reduce building carbon emissions. Some studies introduced building information modeling (BIM) to quantitatively analyze greenhouse gas emissions of prefabricated components [15]. BIM was a very powerful tool, which can be used to identify and evaluate project information in a certain stage or the whole process [16]. In [17], they put forward the method of collecting, analyzing, and visualizing building carbon emission data based on BIM. In [18], they put forward the method of combining BIM and simulation to optimize the architectural design to improve the low-carbon architectural design.

In recent years, the method of optimizing building greenhouse gas emissions by BIM technology was widely used [19]. The design method based on BIM technology provides more building component information than traditional design methods [20]. From the perspective of architectural design, building carbon emission optimization

can only be started in the design phase so that design decision will not be affected [21]. In order to identify factors affecting greenhouse gas emissions from prefabricated components at the design stage, it is necessary to be subject to research objects as the prefabricated components [22]. The designers can quickly evaluate different solutions for prefabricated components based on the BIM model. BIM-based sustainable and fast assessment can provide feedback from timely manner to make a wise choice. For example, by calculating the prefabrication rate of building of the project, the standardization rate of prefabricated components (SRPCs) is evaluated by greenhouse gas emissions of PRBs.

In order to find a design scheme with lower carbon emission for the prefabricated components of PRBs, the prefabricated components are used as a separate study in this paper. In the prefabricated building design stage, a relatively complete boundary model is established to calculate and compare different carbon emission solutions and quantitatively calculate the carbon emission of prefabricated components from a microscopic perspective. This study proposes a method to comprehensively evaluate the carbon emissions of prefabricated components based on the prefabrication rate of building and the standardization rate of prefabricated components. Quantitative calculation software was developed based on the Revit, which was recognized as BIM software, to help architects in decision-making and improve environmental benefit processes.

2. Method

Throughout the domestic and foreign literature review, the environmental impact analysis of existing research on prefabricated buildings was mainly engaged by case comparison, and few studies considered the impact of changes in prefabricated rate and SRPCs on carbon emission in project level. Therefore, this study analyzes the carbon emission of prefabricated components based on the prefabricated rate and SRPCs. The purpose of this study is to reduce the carbon emissions of prefabricated elements by optimizing the standardization rate of prefabricated elements during the building design phase. Compared with other studies, this study categorizes and codes prefabricated elements to allow architects to compare different design options during the design phase. At the same time, based on Revit, this research developed a calculation software for the prefabrication rate of building and standardization rate of prefabricated components to help architects optimizing these quantitative indexes in the design stage.

2.1. Boundary. When calculating carbon emissions accurately, the system calculation boundary must be clarified [1]. Previous studies rarely considered the impact of prefabrication rate of building and standardization rates on project carbon emissions in the design phase. However, architectural design, as the first phase of the entire building life cycle, directly affects building carbon emissions [23, 24]. The project boundary considers all prefabricated components when modeling in LOD100 or LOD200, since it is not known which will be part of the final solution. This method may

TABLE 1: Prefabricated residential component codes.

Technical configuration options		Component code
The prefabricated components of main structure and external envelope Z1	Precast concrete shear wall	JG-HNTGJ-HNTJL
	Prefabricated sandwich insulation exterior wall panel	WWH-JXBWB
	Prefabricated double-layer laminated shear wall panel	JG-HNTGJ-DHJLQ
	Precast concrete shear wall	JG-HNTGJ-HNTJL
	Precast beam	JG-HNTGJ-HNTL
	Prefabricated laminated plate	JG-HNTGJ-DHB
	Precast stair slab	JG-HNTGJ-LTB
	Precast balcony slab	WWH-YTB
	Prefabricated air conditioning panel	WWH-KTB
	PCF concrete external wall hanging plate	JG-HNTGJ-PCF
	Concrete external wall panel	WWH-HNTWG
	Precast concrete bay window wallboard	JG-HNTGJ-PCQB
	Precast parapet	WWH-NEQ
The prefabricated components of internal and external enclosure Z2	Autoclaved lightweight aerated concrete exterior wall slab	WWH-QZWQB
	Light steel keel gypsum board partition wall	NZ-NFGGJ-SGBGQ
	Autoclaved lightweight aerated concrete inner wall panel	WWH-QZWQB
	Reinforced ceramsite concrete lightweight wallboard	NZ-NFGGJ-TLQB
	Integrated kitchen	NZ-JCSCF
Internal equipment Z3	Integrated toilet	NZ-JCSWS
	Fabricated ceiling	NZ-JCSWS
	Floor dry paving	NZ-LDMXT-LDMGS
	Fabricated wall panel (with finish)	NZ-ZPSQB
	Fabricated railing	WWH-LG

lead to overestimation in some cases because certain components may be excluded from the LOD300. To solve this problem, computing boundaries requires using LOD300 BIM model.

Considering the direct and indirect carbon emissions of prefabricated components, the results show that the carbon emissions of building materials reach 96.2%-99% [23]. The total emissions of building materials represent the total emissions of the prefabricated components are reasonable. This study only considers carbon emissions in the production process of prefabricated components, mainly including material consumption and precast form consumption. This study calculates greenhouse gas emissions in the production process of prefabricated components, which include carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbon (HFCs), perfluorocarbon (PFCs), and six sulfur (SF₆) [1]. Carbon dioxide is vast majority of greenhouse gases, thus converting other greenhouse gas emissions into carbon dioxide equivalents.

2.2. Category and Coding. In the process of project calculation, building components are the basic units. Different types of components are in a whole system and are prone to confusion. In order to identify different individual components, it is necessary to classify and code each component according to the building and accurately define the relevant attribute information. However, due to the exchange of

information between each other, in order to correctly understand the information processing and receiving parties without misunderstanding, therefore, a unified coding system is needed to improve the transmission efficiency and accuracy of information. The classification standard is shown in Table 1.

The components are identified by adding a shared parameter when building a BIM model using Autodesk Revit. This work should be implemented in the design stage, so as to play a role in the subsequent production and construction. Information classification coding is two interrelated tasks, one is information classification, and the other is information coding. Only scientific and practical classification can design a coding system that is convenient for computer and human recognition and processing.

2.3. Calculation. This study is suitable for residential building carbon emissions quantitative calculations for assembled concrete structures. Figure 1 shows the prefabricated component carbon emission evaluation process in the design phase: (1) encoding the components in the Revit model; (2) consider the influence of prefabricated component prefabrication rate of building and SRPCs, and compare them with each other; and (3) quantitative calculation of carbon emission of prefabricated components within the project boundary. The prefabricated components are evaluated using the proposed process and quantitative calculations

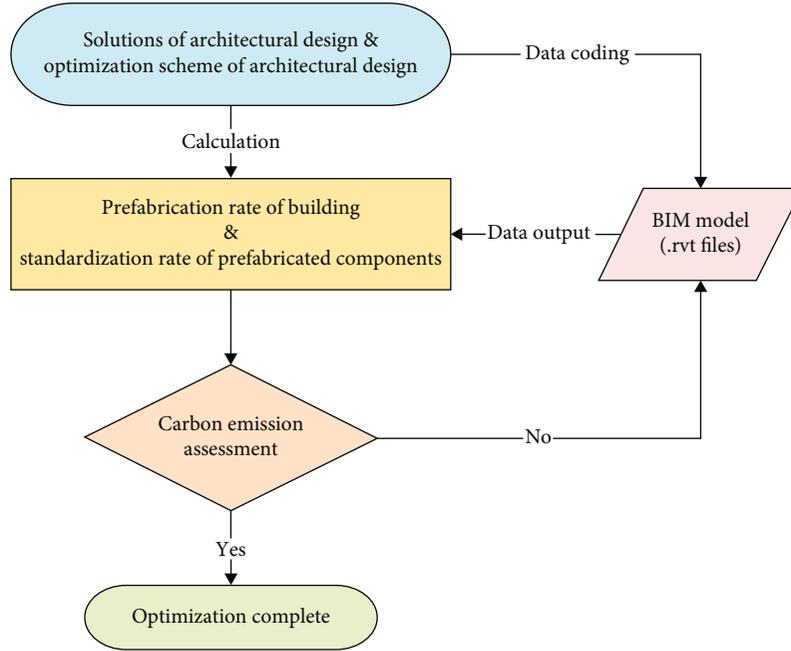


FIGURE 1: Design phase carbon emission evaluation process.

and achieve carbon emission reduction in design phase, which greatly promote the sustainable development of prefabricated buildings.

2.3.1. Prefabrication Rate of Building Calculation. The prefabrication rate of building is an important indicator to evaluate prefabricated buildings, reflecting the degree of application of industrial construction technology in prefabricated buildings. The prefabrication rate of building refers to the volume or area of the prefabricated components above the outdoor floor of the unit building accounts for the ratio of the total area of the part.

$$Z = \sum_i^3 a_i Z_i. \quad (1)$$

In which, Z is a prefabrication rate of building, and a_i is a prefabricated rate calculation weight, of which $a_1 = 0.5$, $a_2 = 0.3$, and $a_3 = 0.2$ (the data is derived from the calculation standard of prefabrication rate of prefabricated buildings in Jiangsu Province).

$$Z_1 = \frac{\sum_i^n ZZWHC}{\sum_i^n ZHC} \times 100\%. \quad (2)$$

In which, Z_1 refers to the prefabrication rate of the main structure and the prefabricated components of the external envelope in the whole building. ZZWHC represents the total volume of precast concrete members of the main structure and enclosure structure of the whole building. ZHC represents the volume of concrete compo-

nents corresponding to the whole building, and i is the type of prefabricated component.

$$Z_2 = \frac{\sum_i^n ZPNWEC}{\sum_i^n ZNWEC} \times 100\%. \quad (3)$$

In which, Z_2 is the prefabrication rate of prefabricated internal and external enclosure components in the whole building. ZPNWEC is the whole total surface area of internal and external maintenance components of prefabricated buildings. ZNWEC is the total surface area of all internal and external maintenance components of the whole building.

$$Z_3 = \frac{\sum_i^n NZBP}{\sum_i^n QBNZBP} \times 100\%. \quad (4)$$

In which, Z_3 represents the prefabricated rate of industrialized internal equipment in the entire building. NZBP represents the projected area or surface area of the entire building industrialized internal equipment. QBNZBP represents the projected area or surface area of all construction parts of the entire building.

2.3.2. Standardization Rate of Prefabricated Component Calculation. This study of prefabricated construction component is introduced into the concept of SRPCs. By controlling the SRPCs, the carbon emissions of prefabricated components are quantitatively analyzed. The purpose of this study is to optimize the carbon emission of prefabricated

TABLE 2: Calculation results of prefabricated components in the case.

Coding	Size (mm)	Count (piece)	SRPCs (%)	STCEs (kg CO ₂ e)	MCEs (kg CO ₂ e)	Carbon emission (kg CO ₂ e)
WWH-YTB	1000 × 200 × 2700	182	68.61	1166.04	65842.69	67008.73
	1200 × 200 × 2700	52		466.42	22574.64	23041.05
	5400 × 150 × 60	52		143.42	1693.10	1836.52
	5200 × 150 × 60	156		276.35	4891.17	5167.52
	1200 × 50 × 1200	208		629.66	30099.51	30729.18
	2800 × 150 × 1200	208		1329.29	70232.20	71561.48
WWH-HNTWG	2900 × 110 × 2900	52	52.00	941.19	32228.08	33169.27
	3200 × 110 × 2900	52		1032.14	35562.02	36594.16
	1450 × 110 × 2900	104		1003.18	32228.08	33231.26
	2000 × 300 × 2900	52		849.27	60617.08	61466.34
	1850 × 300 × 2900	208		2394.75	224283.18	226677.94
JG-HNTDJ-HNTJL	2600 × 300 × 2900	52	60.05	1053.32	78802.20	79855.52
	1300 × 200 × 2900	104		1059.15	52534.80	53593.95
	1100 × 200 × 2900	182		1388.13	77334.67	78722.80
	1850 × 200 × 2900	156		1411.88	112141.59	113553.47
JG-HNTGJ-LTB	2600 × 200 × 2900	26	52.00	946.44	26267.40	27213.84
	3000 × 1200 × 1600	104		2915.13	50429.56	53344.69
	2900 × 1650 × 60	208		1554.04	40007.27	41561.31
JG-HNTGJ-DHB	2900 × 1250 × 60	208	69.33	1201.90	30308.54	31510.43
	2900 × 2900 × 60	208		2654.49	70315.81	72970.30
	3250 × 2800 × 60	208		2864.38	76084.88	78949.26
	1900 × 1400 × 60	208		1522.49	38008.98	39531.47
	2800 × 1750 × 60	208		1842.34	47543.58	49385.92
Total						1310676.41

Note: CO₂e: carbon dioxide equivalent; STCEs: steel template carbon emission; MCEs: material carbon emission.

components by controlling the type and quantity of components in the building design stage.

$$SRPCs_i = \frac{\sum_i CCSC_i / KCCC_i \times 100}{CSF_i} \times 100\%, \quad (5)$$

where $SRPCs_i$ is a SRPCs of single building; $CCSC_i$ is the number of components of the same classification, encoding, and dimensions; $KCCC_i$ represents the number of component openings for the same classification and encoding; CSF_i represents the type of the prefabricated component openings; and i represents the type of components. The component classification and encoding are shown in Table 1.

Through automatic calculations of SRPCs, the architectural designers can quantify the impact of the current design to produce the production of the backend and take this as a reference for further standardized design optimization. According to the national unified construction engineering basic quota, the number of large-steel templates is 200 times, and the number of combined steel templates is 50-120 times. Considering that the number of steel templates will increase, this study sets the number of steel templates to 100 times.

2.3.3. Carbon Emission Calculation. In China, the quantitative calculation of carbon emissions was widely used, so the quantitative calculation of carbon emission in this study can also be accepted. According to China's "Calculation standard of building carbon emission" promulgated in 2019, prefabricated components can only calculate the carbon emissions of building materials. Therefore, it is reasonable to only consider the carbon emissions of the developed component materials in this study. The carbon emission factors of some building materials are shown in Table 2.

To ensure the accuracy of the calculation, choosing a reasonable carbon emission factor is very important. In general, the determination of emission factors can be based on the following aspects [20]: (1) first refer to national, provincial, and industry databases; (2) secondly, refer to the existing research results in domestic literature; (3) refer to foreign databases and research results; (4) direct measurement; and (5) the data that cannot be found or the data quality cannot be guaranteed should not be used and explained in the calculation process.

$$E = \sum_i^n PCW_i \times CEIF_i, \quad (6)$$

TABLE 3: Carbon emission factors of some building materials.

Category of building materials	Carbon emission factors of building materials	Category of building materials	Carbon emission factors of building materials
Ordinary Portland cement	735 kg CO ₂ e/t	Crushed stone ($d = 10 \sim 30$ mm)	2.18 kg CO ₂ e/t
C30 concrete	295 kg CO ₂ e/m ³	Shale rock	5.08 kg CO ₂ e/t
C50 concrete	385 kg CO ₂ e/m ³	Clay	2.69 kg CO ₂ e/t
Lime production (market average)	1190 kg CO ₂ e/t	Plain carbon steel (market average)	2050 kg CO ₂ e/t
Hydrated lime (hydrated lime, calcium hydroxide)	747 kg CO ₂ e/t	PVC (market average)	7300 kg CO ₂ e/t
Natural gypsum	32.8 kg CO ₂ e/t	Tap water	0.168 kg CO ₂ e/t
Sand ($f = 1.6 \sim 3.0$)	2.51 kg CO ₂ e/t		

Note: the greenhouse gas emission factor comes from the calculation standard of building carbon emission.



FIGURE 2: The three-dimensional view and plan of typical floor.

where E represents the carbon emission of a component, PCW represents the weight of the prefabricated component material, CEIF represents the carbon emission coefficient of component material, and i represents the component material Table 3.

3. Case Studies

This study uses the above method to evaluate a PRB in Nanjing. The project has a total of 26 floors and a total building area of 11995.1 m². The three-dimensional view and typical floor plan are shown in Figure 2. According to the statistics of a total of 3198 prefabricated components, the prefabrication rate of the project is 24.29%. The carbon emission calculation of prefabricated components is shown in Table 2.

4. Results and Discussion

This paper takes prefabricated components as the research object and optimizes the carbon emission of prefabricated components as the research goal. To better explain the results of prefabricated component optimization, the carbon emission data of prefabricated components of scheme of architecture design (SAD) and optimization scheme of architecture design (OSAD) are compared in detail. In the

design phase, the model can be quickly extracted and calculated by developing a specific plug-in for Revit. Quantitative analysis of the relationship between carbon emission and optimal design of prefabricated components under the condition of constant prefabrication rate of building.

4.1. Prefabricated Component Carbon Emissions. Optimize WWH-HNTWG, JG-HNTDJ-HNTJL, and JG-HNTGJ-DHB according to China's design specifications. Keep the project prefabrication rate of building (24.29%) unchanged, and the carbon emission variation of prefabricated components is studied by increasing SRPCs. The data standards for the results of prefabricated components for optimizing architectural design are shown in Table 4.

Figure 3 shows that building optimization can significantly reduce carbon emissions from prefabricated components. After optimization, the carbon emission is reduced by 2034.16 kg CO₂e, accounting for 0.1552% of the total carbon emissions of prefabricated components. These findings confirm the importance of efficient prefabricated component design in PRBs. Research shows that designers can reduce the carbon emissions of PRBs by improving the SRPCs in the design stage. Considering these design factors, designers can optimize the design scheme of prefabricated components to achieve low-carbon design.

TABLE 4: Prefabricated component carbon emissions of alternative solutions to optimize architectural design.

Coding	Size (mm)	Count (piece)	SRPCs (%)	STCEs (kg CO ₂ e)	MCEs (kg CO ₂ e)	Carbon emission (kg CO ₂ e)
WWH-YTB	1000 × 200 × 2700	182	68.61	1166.04	65842.69	67008.73
	1200 × 200 × 2700	52		466.42	22574.64	23041.05
	5400 × 150 × 60	52		143.42	1693.10	1836.52
	5200 × 150 × 60	156		276.35	4891.17	5167.52
	1200 × 150 × 1200	208		629.66	30099.51	30729.18
WWH-HNTWG	2800 × 150 × 1200	208	60.67	1329.29	70232.20	71561.48
	1450 × 110 × 2900	208		1504.77	64456.16	65960.93
	3200 × 110 × 2900	52		1081.99	35512.17	36594.16
	2000 × 300 × 2900	104		1698.53	121234.15	122932.68
JG-HNTDJ-HNTJL	1850 × 300 × 2900	208	70.06	2394.75	224283.18	226677.94
	600 × 300 × 2900	52		373.13	18185.12	18558.26
	1300 × 200 × 2900	156		1059.15	78802.20	79861.35
JG-HNTGJ-LTB	1100 × 200 × 2900	182	52.00	1388.13	77334.67	78722.80
	1850 × 200 × 2900	156		1411.88	112141.59	113553.47
	3000 × 1200 × 1600	104		2915.13	50429.56	53344.69
JG-HNTGJ-DHB	2900 × 1650 × 60	416	74.88	2590.07	80014.54	82604.61
	2900 × 1250 × 60	416		2003.16	60617.08	62620.24
	3250 × 1400 × 60	632		2864.38	76084.88	78949.26
	1900 × 1400 × 60	208		1522.49	38008.98	39531.47
	2800 × 1750 × 60	208		1842.34	47543.56	49385.9
Total						1308642.25

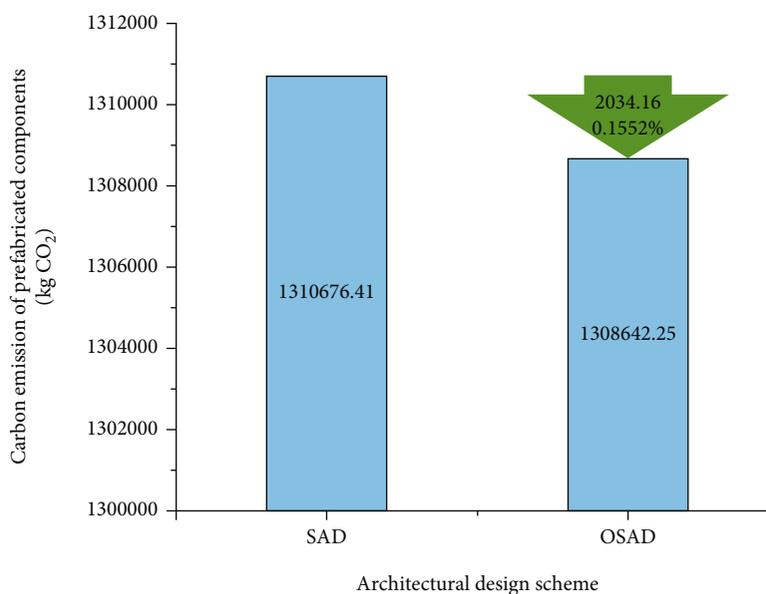


FIGURE 3: Comparison of carbon emissions for prefabricated components.

In this study, a design with lower carbon emissions is obtained by optimizing the design of prefabricated components. Figure 3 is the result analysis diagram of carbon dioxide emissions before optimization of SRPCs (as shown in Table 3) and carbon emissions after optimization. By raising

SRPCs in the design phase of prefabricated building, the turnover and utilization of steel formwork in the production of prefabricated components is increased, thereby leading to reduction of the carbon dioxide emissions of prefabricated components.

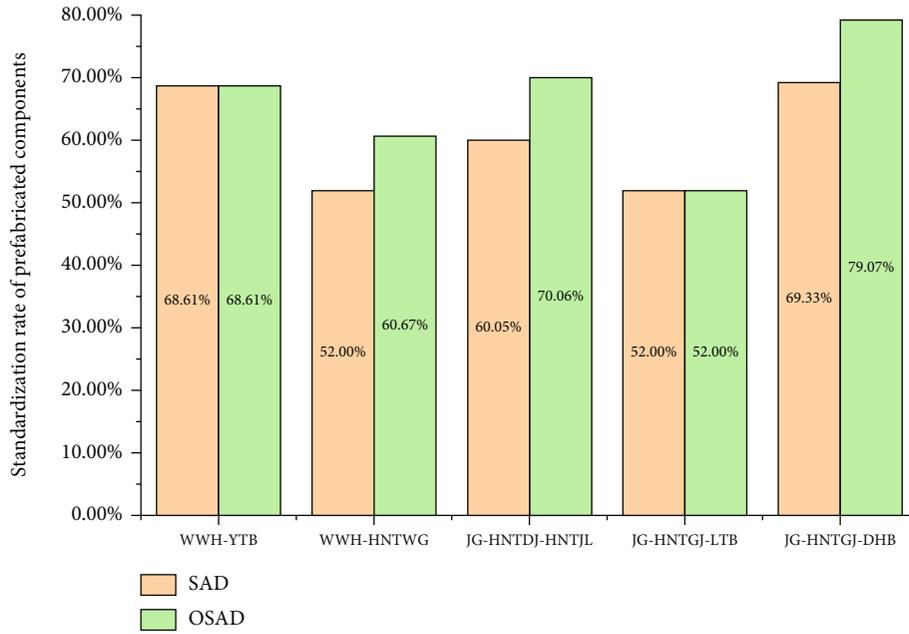


FIGURE 4: Comparison of SRPCs.

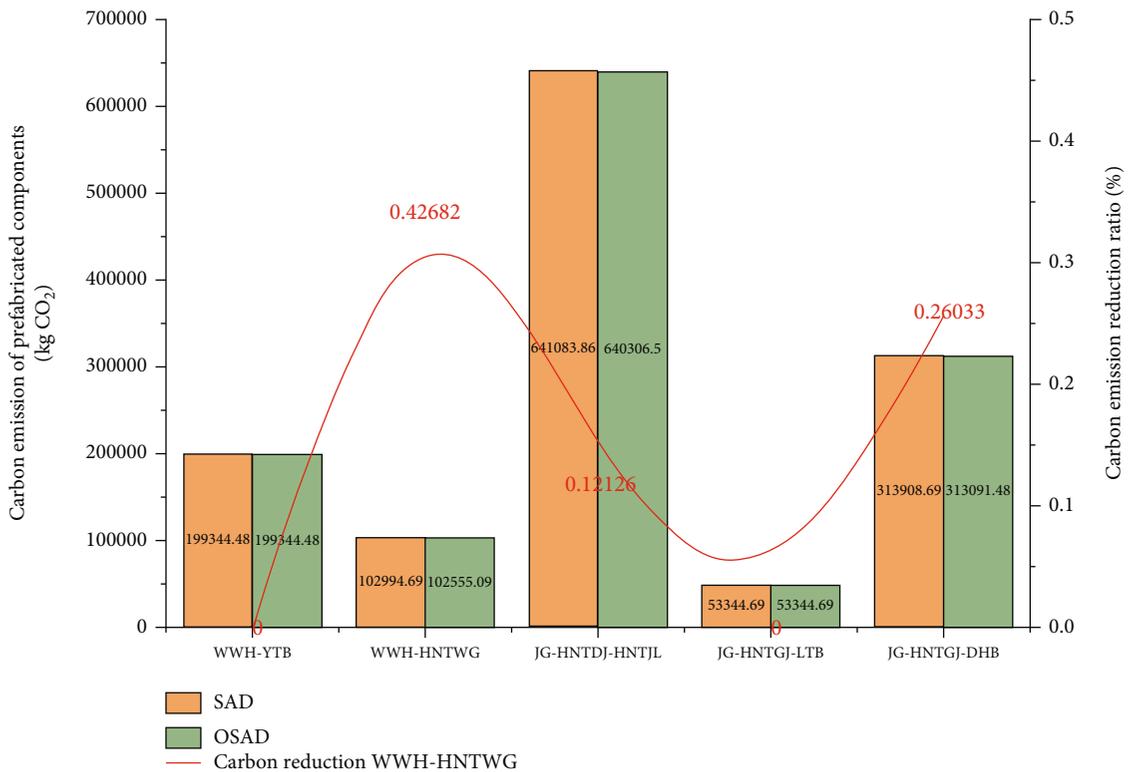
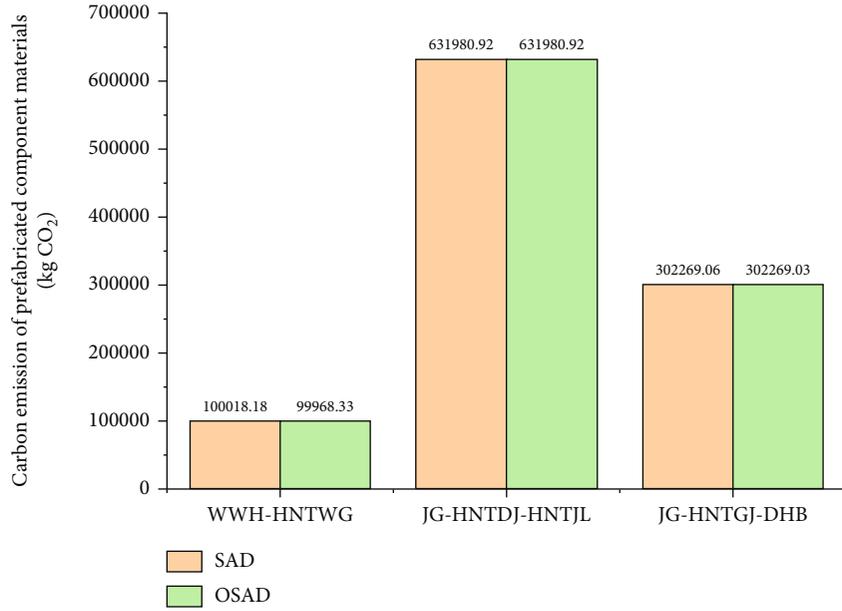


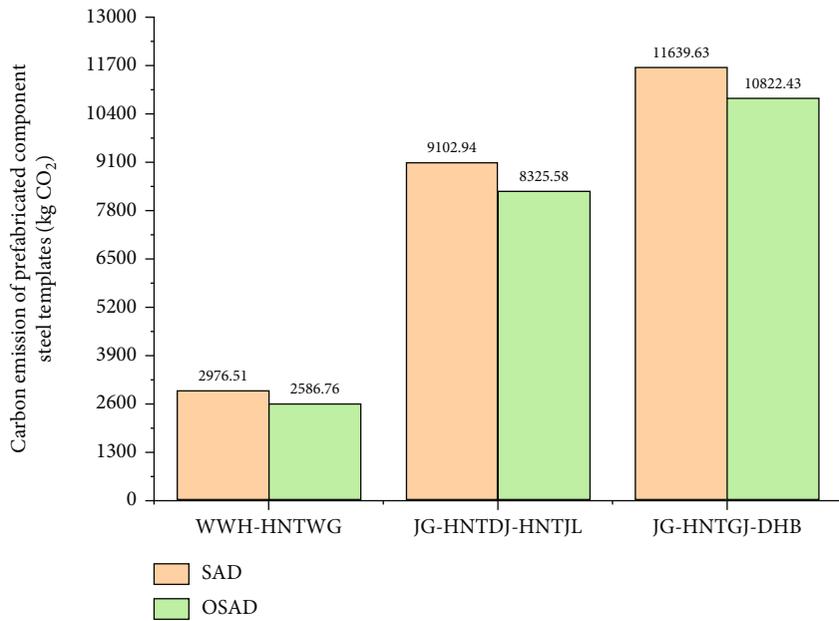
FIGURE 5: Comparison of carbon emissions for prefabricated components.

BIM and prefabricated buildings are both component-based systems; adopting BIM technology in prefabricated building can bring huge advantage of management. BIM is also a process which could comply with data collecting of prefabricated components and visualizing it successively. The traditional way of expressing project information was delivered via paper storage; that phenomenon leads to the

occurrence of “information island.” In this study, prefabricated components are classified and coded to facilitate information extraction and calculation of prefabricated components. At the same time, the calculation plug-in software based on Revit can help architects to calculate the prefabrication rate of building instantly, as well as SRPCs and the carbon emissions of them. It can help architects making



(a) Carbon emission comparison of prefabricated component materials



(b) Carbon emission comparison of prefabricated component steel templates

FIGURE 6: Carbon emission comparison of prefabricated component materials and template.

design decisions and also help reducing the carbon emissions of single-fabricated building during the design stage.

4.2. Sensitivity Analysis. Carbon emissions of PRBs may be affected by prefabrication rate of building, SRPCs, and calculation boundaries of prefabricated components. Despite possible deviations, it is feasible to quantify carbon emissions from prefabricated components in different designs. In the calculation process, the calculation boundary and the prefabrication rate of building (24.29%) remain unchanged. In this study, the sensitivity of SRPCs is analyzed to determine the effectiveness of SRPCs to reduce carbon emissions.

On this basis, this paper analyzes SRPCs and carbon emission of prefabricated components (as shown in Figures 4 and 5). The SRPCs of WWH-HNTWG increase by 8.67%, carbon emission decrease by 0.42682%, and 439.60 kg CO₂e. The SRPCs of JG-HNTDJ-HNTJL increase by 10.01%, carbon emission decrease by 0.12126%, and 777.36 kg CO₂e. The SRPCs of JG-HNTGJ-DHB increase by 9.74%, carbon emission decrease by 0.26033%, and 817.21 kg CO₂e.

The comparison before and after the optimization design of prefabricated component materials and prefabricated template is shown in Figure 6. By optimizing the prefabrication rate of the prefabricated components, the carbon

emissions of the prefabricated component materials are basically unchanged, and the carbon emissions of the prefabricated component template significantly reduced. The prefabricated component template of WWH-HNTWG carbon emissions reduce by 13.09% and 389.75 kg CO₂e. The prefabricated component template of JG-HNTDJ-HNTJL carbon emissions decrease by 8.54% and 777.36 kg CO₂e. The prefabricated component template of JG-HNTGJ-DHB carbon emissions decrease by 7.02% and 817.21 kg CO₂e.

A sensitivity analysis of carbon emissions from prefabricated components is presented to show the impact of SRPCs on carbon emissions and assess the design plan. In the context of information technology, interdisciplinary research has attracted more and more attention, and the research of BIM technology on PRBs has been further expanded. In the context of China's construction industrialization, this study can make up for the lack of current research on prefabricated components.

5. Conclusion

This paper evaluates the effectiveness of improving the SRPCs by calculating the prefabrication rate of building and SRPCs. The model is mainly used to control the carbon emissions of prefabricated components in the design stage. Architects can reduce the carbon emissions of prefabricated components by optimizing SRPCs in the design stage effectively. The calculation results of the study case show that, by improving the SRPC, the carbon emissions of prefabricated components are reduced by 2034.1 kg CO₂, which occupies 0.1552% of all prefabricated components. Therefore, this study can effectively reduce the carbon emissions of components by optimizing SRPCs under the condition of constant prefabrication rate of building, which provides a basis for decision-making in the design stage. This paper believes that the method of evaluating PRBs by SRPCs is commonly used and can be migrated to other PRB projects in different regions.

The calculation results show that it is feasible to optimize SRPCs in the prefabricated building design stage to reduce the single prefabricated building, which can provide architects with a low-carbon prefabricated design basis. In addition, future research areas include (1) ending prefabricated components with more attribute information providing more financial data and (2) evaluating the impact of SRPCs on building energy consumption.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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