# Study on carbon emission evaluation and influencing factors of prefabricated buildings

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**Abstract.** Prefabricated buildings under the "double carbon" target have significant advantages in energy saving and emission reduction, so it is of great significance to explore the influencing factors of carbon emission. In order to effectively improve the carbon emission efficiency of prefabricated buildings, a comprehensive evaluation model of carbon emission factors of prefabricated buildings was established by using AHP-fuzzy comprehensive evaluation method. Firstly, on the basis of comprehensive analysis of the influencing factors of carbon emissions of prefabricated buildings, an evaluation index system of carbon emissions of prefabricated buildings including 5 first-level indicators and 20 second-level indicators was established. Ahp was applied to determine the weights of indicators at all levels, and fuzzy mathematical model for carbon emissions evaluation of prefabricated buildings was established by fuzzy theory. According to the fuzzy comprehensive safety evaluation model, a prefabricated building project is evaluated. The evaluation results show that the overall carbon emission evaluation results of the prefabricated building are "generally important". This example verifies that prefabricated buildings should pay more attention to carbon emissions, and puts forward corresponding countermeasures and suggestions in order to promote the development of carbon emission system of prefabricated buildings and improve the carbon emission efficiency of prefabricated buildings, so as to provide reference for promoting the construction industry to achieve the double carbon goal.

**Keywords:** Prefabricated building; Carbon emission; AHP-fuzzy comprehensive evaluation method

## 1 Introduction

As an important pillar industry of national economy in China, construction industry is accompanied by high pollution and high energy consumption in the construction operation stage, and the annual emission of carbon $CO_2$ accounts for 36% of the world's total carbon $CO_2$ [1]. At present, China is in the initial stage of realizing the double carbon goal, and the total carbon emission of the whole construction process in the country has increased or decreased, but the overall trend is rising. Therefore, it is of


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great practical significance to study the life cycle carbon emission of prefabricated buildings and determine the influencing factors for carbon emission management of prefabricated buildings.

With the development of prefabricated buildings, the research on carbon emissions during the prefabricated building life cycle has made some achievements. Sandanayake, a foreign scholar, took two projects as examples to analyze the change of carbon emissions between the foundation and the construction stage of the built buildings[2]. Nasab's analysis of carbon emission factors for prefabricated buildings takes into account raw material manufacturing, transportation and construction equipment[3]. Domestic researchers have also carried out corresponding research on carbon emissions of prefabricated buildings. Taking a project in Shenzhen as an example, Gao Yu calculated the carbon emissions of each stage based on the energy consumption data of the production, transportation and assembly stages of prefabricated components[4]. The study concluded that the high carbon emissions in the production stage were mainly caused by the large number of steel bars in the shear wall and composite beam[5-7]. When Sun Yanli compared the carbon emission of the prefabricated building in the construction stage of Honghui Park project with that of the cast-in-place part, the measurement results showed that the carbon emission of the prefabricated part was significantly reduced, and the mortar was reduced by 95%[8]. It can be seen that the research on carbon emission of prefabricated buildings mainly focuses on the carbon emission calculation of the main body of prefabricated buildings and the research on the influencing factors of carbon emission of prefabricated buildings. At present, the influencing factors of carbon emission of prefabricated buildings mainly consider each link of individual buildings, and there is a lack of macro-level analysis, and the factors affecting carbon emission system of prefabricated buildings at the macro-level should not be underestimated. Therefore, this paper mainly analyzes the factors affecting the development of prefabricated buildings and their carbon emissions from a macro perspective, in order to provide references for improving their carbon emission benefits.

Based on this, in order to evaluate the influencing factors of carbon emissions of prefabricated buildings, the hierarchical analysis and fuzzy comprehensive evaluation method are used to comprehensively evaluate carbon emissions of prefabricated buildings. Firstly, the carbon emission evaluation index system of prefabricated buildings was constructed through literature research, expert interview and other means. Then, the expert group scored and obtained the weight coefficient of indicators at each level through analytic hierarchy process, and established a fuzzy mathematical model for carbon emission evaluation of prefabricated buildings by using fuzzy theory, taking a prefabricated building as an example. The constructed analytic hierarchy process and fuzzy comprehensive evaluation model are used to evaluate the carbon emission of the prefabricated building, and corresponding measures are proposed, which is of great significance for reducing the carbon emission of the prefabricated building and promoting the prefabricated building, and provide theoretical reference for future research on carbon emission of the prefabricated building.

## 2 The Selection of Evaluation Index and the Establishment of System

With its advantages of reduced carbon emissions, energy conservation, and great effectiveness, prefabricated buildings have become a research hotspot for scholars at home and abroad, and will develop rapidly under the promotion of relevant national policies. By analyzing related literature on the development of prefabricated construction field and influencing factors of building carbon emission, the screening scope of influencing factors of prefabricated building carbon emission was expanded, and the influencing factors were initially screened out[9-10]. The list of influencing factors initially selected was extracted by expert consultation method. A total of 10 experts in the fields of prefabricated building development, energy consumption and building carbon emission were invited for consultation until a consensus was reached. After comprehensive consideration of macro and micro levels, the carbon emission factors of prefabricated buildings are finally sorted out under five dimensions: economic population, technological development, government decision-making, market environment and energy consumption.

A factor set is made up of all the different factors that have an impact on the assessment item. It is essential to a reasonable, fuzzy, scientific, and thorough evaluation. It is able to be stated as V={$V_1, V_2$, …, $V_n$}, where$V_i$(i=1,2, …,n) are several influencing factors. The selection of evaluation factors should be as comprehensive as possible and should be highlighted. If you consider too many factors and too much detail to determine the weight of the factors may be too small, or even zero. Therefore, necessary screening is required, the carbon emission evaluation index system of prefabricated buildings was established, as shown in Table 1.

**Table 1.** Carbon emission evaluation index system of prefabricated buildings

| Primary index | Secondary index |
|---|---|
| Economic factor $V_1$ | $V_{11}$Per capita GDP |
| | $V_{12}$Residents' consumption level |
| | $V_{13}$Investment in scientific research and innovation |
| Energy factor $V_2$ | $V_{21}$Carbon reduction cost |
| | $V_{22}$Energy efficiency |
| | $V_{23}$Building energy consumption |
| | $V_{24}$Building carbon emission |
| Policy factors $V_3$ | $V_{32}$ Perfection of laws and regulations |
| | $V_{33}$ technical standard specification degree |
| | $V_{34}$Government subsidy policy for carbon emission reduction |
| | $V_{35}$Carbon emission tax incentives related policies |
| Market factor $V_4$ | $V_{41}$ Prefabricated building construction cost |
| | $V_{42}$ Prefabricated building scale |
| | $V_{43}$ The degree of cooperative work of the main body is low |
| | $V_{44}$The enthusiasm of the participants is not enough |
| Technical factor $V_5$ | $V_{51}$Quality standardization of prefabricated components |

| | |
|---|---|
| | $V_{52}$Level of supporting production tools |
| | $V_{53}$The technical level of the employees |
| | $V_{54}$Assembly technology level |

# 3 The Index Weight is Determined Based on Analytic Hierarchy Process

In this evaluation method, determining the weight of each level of evaluation factors is the most critical part of establishing the whole evaluation system. This paper will use analytic hierarchy process to determine the weights of evaluation factors at all levels. The following is the determination process of weights at all levels.

## 3.1 Establishment of Discriminant Matrix

The discriminant matrix of primary factors is obtained by pairwise comparison according to the importance of each factor. The discriminant matrix of secondary factors in the same group is obtained by pairwise comparison according to the importance of each factor. The criterion of discriminant matrix scaling is shown in Table 2, 1-9 scaling method.

**Table 2.** 1-9 Scaling methods

| cale | implication |
|---|---|
| 1 | Indicates that two elements are equally important when compared |
| 3 | Indicates that the former is slightly more important than the latter |
| 5 | Indicates that the former is significantly more important than the latter |
| 7 | Indicates that the former is more important than the latter |
| 9 | Indicates that the former is more important than the latter |
| 2,4,6,8 | Represents the median value of the above neighboring judgments |
| Count backwards | If the ratio of importance of element i to element j is $a_{ij}$, then the ratio of importance of element j to element i $a_{ji}=1/a_{ij}$ |

## 3.2 Determine the Weight of Each Factor

The weight of each factor is determined by discriminating the eigenvector corresponding to the largest eigenroot of the matrix and carrying out normalization processing. Matlab software is used to process the discriminant matrix, and the consistency test is carried out to meet the requirements, and the following prefabricated building Table 3 is obtained:

**Table 3.** Weight of carbon emission evaluation index of prefabricated buildings

| Primary index | weight | Secondary index | weight |
|---|---|---|---|
| $B_1$ | 0.065 | $V_{11}$ | 0.158 |
| | | $V_{12}$ | 0.187 |

| | | | |
|---|---|---|---|
| | | $V_{13}$ | 0.655 |
| $B_2$ | 0.105 | $V_{21}$ | 0.097 |
| | | $V_{22}$ | 0.182 |
| | | $V_{23}$ | 0.247 |
| | | $V_{24}$ | 0.474 |
| $B_3$ | 0.138 | $V_{31}$ | 0.064 |
| | | $V_{32}$ | 0.100 |
| | | $V_{33}$ | 0.170 |
| | | $V_{34}$ | 0.249 |
| | | $V_{35}$ | 0.418 |
| $B_4$ | 0.239 | $V_{41}$ | 0.128 |
| | | $V_{42}$ | 0.222 |
| | | $V_{43}$ | 0.269 |
| | | $V_{44}$ | 0.381 |
| $B_5$ | 0.453 | $V_{51}$ | 0.086 |
| | | $V_{52}$ | 0.174 |
| | | $V_{53}$ | 0.308 |
| | | $V_{54}$ | 0.431 |

# 4 The Safety Level is Determined Based on Fuzzy Comprehensive Evaluation

In this paper, a prefabricated building is taken as an application example, and the whole life cycle of the prefabricated building is evaluated by fuzzy comprehensive analysis based on analytic hierarchy process. The total construction area of the prefabricated building is 64,394.72 square meters, and the project includes floor foundation and foundation engineering, main structure engineering, building decoration and decoration engineering, roofing engineering, and building energy conservation engineering; The design service life is 50 years.

## 4.1 Index Evaluation Grade Assignment

Through literature, data inquiry and expert consultation, the indicators in the carbon emission evaluation index system of prefabricated buildings were divided into five evaluation grades, namely 1 (very important), 2 (important), 3 (generally important), 4 (unimportant) and 5 (completely unimportant). Each grade corresponds to a different score value in Table 4. Therefore, the evaluation standard table was established, as shown in Table 5.

**Table 4.** Risk assessment levels

| Lv. | Very important | importance | General importance | unimportance | Totally unimportant |
|---|---|---|---|---|---|
| mark | (8,10] | (6,8] | (4,6] | (2,4] | (0,2] |

**Table 5.** Carbon emission factor evaluation table of prefabricated buildings

| Secondary index | Evaluation statistics | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| $V_{11}$ | 0.2 | 0.3 | 0.4 | 0.1 | 0 |
| $V_{12}$ | 0.4 | 0.3 | 0.2 | 0.1 | 0 |
| $V_{13}$ | 0.3 | 0.3 | 0.2 | 0.2 | 0 |
| $V_{21}$ | 0.3 | 0.3 | 0.2 | 0.1 | 0.1 |
| $V_{22}$ | 0.4 | 0.2 | 0.2 | 0.1 | 0.1 |
| $V_{23}$ | 0.1 | 0.1 | 0.5 | 0.3 | 0 |
| $V_{24}$ | 0.3 | 0.1 | 0.3 | 0.2 | 0.1 |
| $V_{31}$ | 0.4 | 0.3 | 0.2 | 0.1 | 0 |
| $V_{32}$ | 0.3 | 0.1 | 0.2 | 0.4 | 0 |
| $V_{33}$ | 0.2 | 0.3 | 0.2 | 0.2 | 0.1 |
| $V_{34}$ | 0.4 | 0.2 | 0.1 | 0.3 | 0 |
| $V_{35}$ | 0.2 | 0.3 | 0.3 | 0.1 | 0.1 |
| $V_{41}$ | 0.4 | 0.2 | 0.1 | 0.2 | 0.1 |
| $V_{42}$ | 0.2 | 0.2 | 0.4 | 0.2 | 0 |
| $V_{43}$ | 0.3 | 0.2 | 0.2 | 0.3 | 0 |
| $V_{44}$ | 0.3 | 0.3 | 0.1 | 0.2 | 0.1 |
| $V_{51}$ | 0.2 | 0.2 | 0.1 | 0.3 | 0.2 |
| $V_{52}$ | 0.3 | 0.3 | 0.2 | 0.2 | 0 |
| $V_{53}$ | 0.4 | 0.2 | 0.3 | 0.1 | 0 |
| $V_{54}$ | 0.2 | 0.2 | 0.2 | 0.3 | 0.1 |

## 4.2 Fuzzy Comprehensive Evaluation Mathematical Model

When the weight vector W and the evaluation matrix V are known, the comprehensive evaluation is carried out by fuzzy transformation. The mathematical model of fuzzy comprehensive evaluation is calculated, B' is obtained after normalization, B' is multiplied by fuzzy evaluation vector V, and the final score is obtained. According to the calculation, the primary index and membership degree summary data, membership degree data and comprehensive evaluation scores are obtained, and the specific results are shown in Table 6-8 below:

**Table 6.** Summary table of first-level indicators and membership degree

| Primary index | weight | Membership degree | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| B1 | 0.065 | 0.094609 | 0.189218 | 0.283827 | 0.378437 | 0.053909 |
| B2 | 0.105 | 0.300000 | 0.100000 | 0.300000 | 0.200000 | 0.100000 |
| B3 | 0.138 | 0.213169 | 0.268695 | 0.268695 | 0.159877 | 0.089565 |
| B4 | 0.239 | 0.262176 | 0.262176 | 0.203442 | 0.184813 | 0.087392 |
| B5 | 0.453 | 0.259832 | 0.181765 | 0.194874 | 0.272647 | 0.090882 |

**Table 7.** Membership degree of carbon emission comprehensive evaluation of prefabricated buildings

| evaluate | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Membership degree | 0.2413261 | 0.2151625 | 0.2156808 | 0.2381234 | 0.0897072 |

**Table 8.** Comprehensive score table

| Primary index | B1 | B2 | B3 | B4 | B5 | Comprehensive evaluation |
|---|---|---|---|---|---|---|
| score | 2.226876 | 1.434151 | 1.119645 | 0.706023 | 0.088421 | 5.575116624 |

## 5 Conclusions

The evaluation model is used to fully analyze the experts' evaluation of the index value. By comparing the carbon emission risk evaluation grade table of prefabricated buildings, 4<5.58<6, it is determined that the carbon emission grade of the prefabricated buildings is "generally important". According to the theoretical calculation and analysis of the influencing factors of prefabricated building carbon emissions mentioned above, the following countermeasures and suggestions can be put forward for the five factors with relatively high weight ratio:

(1) Improve policy recommendations and raise the low carbon awareness of relevant parties. First of all, government authorities can regularly plan public relations activities for prefabricated buildings to raise the interest of stakeholders, promote low-carbon and socially responsible construction practices, and highlight the advantages of prefabricated buildings. Second, after the government approves the funds, the funds are allocated to construction companies or manufacturers of building components that meet the relevant policy requirements. The allocation of these funds is accompanied by clear conditions, thus strengthening its policy guidance role. Finally, enhance the market scale effect of large enterprises, integrate low-carbon concepts into the value chain of enterprises, build green low-carbon value chain of prefabricated buildings, actively participate in prefabricated building projects invested by the government, and promote low-carbon emission reduction of enterprises.

(2) Increase the market share of prefabricated buildings. In order to speed up the construction progress, reduce the additional cost of project construction, and solve the problem of operation and management of prefabricated buildings, EPC general contract management mode is adopted. On the other hand, relying on BIM technology to reduce the transportation distance cost, rational layout of industrial enterprises, and the use of this technology to establish prefabricated structure carbon emission measurement platform. The use of BIM technology to minimize unnecessary waste of resources and maximize the dynamic management of building materials.

(3) Improve the technical level of prefabricated buildings. Firstly, to improve the quality of prefabricated buildings, it is necessary to strengthen the training of professional and technical personnel, installation personnel and on-site management personnel. The second is to strengthen the construction technology innovation of prefabricated

buildings, and improve the utilization efficiency while reducing energy consumption. Increase investment in scientific and technological innovation, encourage key node connection technology innovation in prefabricated buildings, and break through the bottleneck of key node connection technology. Finally, it is to actively research and develop innovative low-carbon recyclable materials, as well as intelligent and green construction and operation and maintenance technology.

This paper focuses on the development of prefabricated buildings, carries out hierarchical analysis on 20 selected factors that affect the carbon emission of prefabricated buildings, and on this basis, adopts fuzzy comprehensive evaluation to determine its membership degree, and puts forward corresponding countermeasures and suggestions, in order to promote the development of carbon emission system of prefabricated buildings, improve the carbon emission efficiency of prefabricated buildings, and provide for promoting the realization of the dual-carbon goal of the construction industry.

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