Research and application of carbon footprint correction method in construction of new building evaluation model

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Abstract. This article cites a carbon footprint correction method and uses it to build an evaluation model for new buildings. By introducing a carbon footprint correction method, the goal is to build a high-efficiency, low-energy consumption evaluation model for new buildings. Comprehensively consider 15 indicators of 4 dimensions, including residential environment, energy efficiency and carbon footprint, then calculate the weight of each indicator and assign value analysis to it, and construct the evaluation model of the new building, and finally use the deviation rate of the carbon footprint to modify the evaluation level. This research can provide a usable evaluation model for the construction of new buildings, so as to scientifically and reasonably guide the planning and construction of new buildings with high efficiency and low energy consumption.

1. Introduction
In the process of social development and progress, while enjoying the joy brought by economic development, people have also caused great pollution and damage to the development and utilization of nature. Buildings are the basic carrier for realizing the construction of ecological civilization. Therefore, the building is an important place and important way to realize ecological civilization. According to statistics, among the total pollution sources, industrial pollution accounts for only 41%, and it is surprising that domestic pollution is as high as 59% [1]. It can be seen that the building, as the place where people live, is also the main manufacturing place for living pollution. Therefore, research on new buildings has become an important topic for sustainable development.

Internationally, research on new buildings originates from the concept of "ecological architecture". In 1965, "Design World and Nature" was published in the United States. It emphasizes the harmonious coexistence of people, architecture, society and nature. China has promulgated the "New Building Evaluation Standards", "China Ecological Housing Technology Evaluation Standards", and "Eco-House Environmental Labeling Product Certification Standards". It can be seen that energy conservation, emission reduction and energy utilization are important contents in the research of new Buildings. Weiding Long and others proposed [2] to use the "per capita carbon emissions in building utilization" and "carbon emission reduction efficiency in building energy use processes" indicators to evaluate the carbon emissions during the use of buildings. This shows that the carbon emissions generated by buildings during their lifetime are more from human behavior. Based on the life cycle assessment theory proposed by Gao Yuan et al. [3], The system boundaries and inventory contents of urban building life cycle carbon emission assessment were defined, and a micro-level urban building life cycle carbon
emission accounting model was established. The above research results show that the research on carbon emissions generated by buildings has become a research hotspot today, and these studies provide relevant scientific theoretical support for the development of low-carbon buildings and new buildings. This shows that the research on the decarbonization of new building construction is of great significance.

2. Construction of new building evaluation system

In constructing the evaluation system of new buildings, this article refers to the LEED-ND in the United States, Ecohomes in the United Kingdom and the "New Building Evaluation Standards", "Chinese Ecological Housing Technology Evaluation Standards", and "Eco-House Environmental Labeling Product Certification Standards". On the other hand, this paper refers to the carbon footprint theory, which mainly calculates the carbon footprint generated during the operation phase, and then uses the deviation rate of the carbon footprint as a standard to measure the level of energy conservation and emission reduction.

2.1. Hierarchy of the evaluation system

Before establishing the evaluation system, by drawing a hierarchical structure chart of the new building evaluation system, sort out the planning of the building system categories of the new building. Combined with the establishment basis of the above indicators and Delphi method, the hierarchy chart of the evaluation system is drawn, as shown in Figure 1.

![Hierarchy structure of new building evaluation system.](image-url)
2.2. Determination of indicator weight

2.2.1. Method for determining indicator weight. The method of determining the index weight in this article is the analytic hierarchy process, which is a more commonly used and mature method [4]. This article made some changes to the conventional analytic hierarchy process and got an improved analytic hierarchy process that is more suitable for the new building evaluation system studied in this article. As shown in Table 1, its characteristic is to use the three-point method instead of the nine-point method to establish a judgment matrix.

| Scale value | Meaning                              |
|-------------|--------------------------------------|
| 1           | A factor is more important than B factor |
| 0           | A and B are equally important         |
| -1          | A factor is less important than B factor |

Table 1. Three-point scale value and its meaning.

2.2.2. Calculation of indicator weights. In order to collect relevant data, based on the evaluation system of new Buildings, this article designs a questionnaire for comparison of evaluation indicators, and sends questionnaires to relevant experts, scientific research institutions, and the government, and returns 94 of which 83 are valid. The questionnaire is based on the principle of analytic hierarchy process to determine the weight of various factors, so the focus of the work is to compare the two elements of the indicators. We collated the survey results of valid questionnaires, and then tested the reliability and validity. The test results met the requirements. Through the understanding of the improved hierarchical method and the questionnaire of the weight questionnaire, the weight of each index item of the new building evaluation system is calculated. Taking the first level indicators of the evaluation system as an example, this level includes four indicators, namely, reducing environmental load, improving health and comfort, operation management and economy, which are expressed by \( Q_1 \), \( Q_2 \), \( Q_3 \) and \( Q_4 \) respectively. According to the scores of the questionnaire, and after the unified treatment, the importance comparison table of this level can be established, as shown in Table 2.

Table 2. Comparison table of the importance of the first-level indicators of the evaluation system.

| First-level indicators | \( Q_1 \) | \( Q_2 \) | \( Q_3 \) | \( Q_4 \) |
|------------------------|----------|----------|----------|----------|
| \( Q_1 \)              | 0        | -1       | 1        | 1        |
| \( Q_2 \)              | 1        | 0        | 1        | 1        |
| \( Q_3 \)              | -1       | -1       | 0        | 1        |
| \( Q_4 \)              | -1       | -1       | 1        | 0        |

A matrix is established by comparing the indicators one by one, and then calculated according to the analytic hierarchy process. The weights of the new building-level indicators are: \( Q_1=0.23 \), \( Q_2=0.46 \), \( Q_3=0.17 \), and \( Q_4=0.10 \). The same method can be used to calculate the weight of the secondary index to the upper layer. The index weight of the building location is taken as an example for illustration. If the single-level weight is obtained, the weight of the final index item to the overall target can be obtained. Similarly, the weight of all indicators can be calculated in the same way.

3. Calculation of carbon footprint correction

The carbon footprint calculated in this article is set during the operational phase of the building. Because in the entire life cycle of a building, the building operation period lasts for a long period, high energy consumption, and large carbon emissions, the main factors that determine its carbon footprint are the newness of the building and the living habits of users. The evaluation of the carbon footprint during the operation and use phase is carried out from three perspectives, namely, residential life, building facilities, maintenance and update. The carbon footprint is calculated using the emission factor method. The
carbon footprint is calculated by counting the consumption of various energy sources and querying the corresponding carbon emission factors. The carbon emission factors used data from the China Energy Statistical Yearbook.

3.1. Calculation of carbon footprint of residents’ lives

The carbon footprint of residents is generated by the daily life of residents and buildings. The carbon footprint calculation mainly includes water, electricity, gas, gas, transportation, etc.[5]. We use $U_R$ to represent the carbon footprint of residents’ lives; $E_i$ to represent the consumption of the i-th energy source; and $Y_i$ to represent the carbon emission factor of the i-th energy source. Calculated as follows:

$$U_R = \sum_{i=1}^{n} E_i \times Y_i$$  \hspace{1cm} (1)$$

3.2. Carbon footprint calculation for building facilities

The building's facilities include water-saving facilities, garbage recycling facilities, lighting facilities, public leisure facilities, transportation facilities, newing facilities, and property management functions. The carbon footprint of building facilities needs to be calculated from overall energy and water use. We use $U_S$ to represent the carbon footprint of building facilities. Calculated as follows:

$$U_S = \sum_{i=1}^{n} E_i \times Y_i$$  \hspace{1cm} (2)$$

3.3. Maintain updated carbon footprint calculations

With the operation and use of buildings, some components will age and need to be replaced or repaired, such as water supply and drainage pipes, coatings, doors and windows, ventilation ducts, roof structural layers, etc.. This part of the carbon footprint calculation needs to statistically update the amount of materials used to find the corresponding carbon emission factor. We use $U_M$ to represent the carbon footprint of maintenance updates. Calculated as follows:

$$U_M = \sum_{i=1}^{n} E_i \times Y_i$$  \hspace{1cm} (3)$$

The total carbon footprint generated during the operational phase is expressed in UT, so:

$$U_T = U_R + U_S + U_M$$  \hspace{1cm} (4)$$

The carbon footprint calculation above reflects the carbon emissions generated by the building as a whole during the operation phase. The total carbon footprint due to factors such as land area and population cannot be used to fully measure the building's low carbon level[6]. Evaluation benchmarks are used to measure the carbon footprint of a building. The benchmark value used in this article is the weighted average of the carbon footprints of the participating new Buildings. We use $P$ to denote the carbon footprint of the building. $P_j$ represents the carbon footprint of the j-th building; $H_j$ represents the total number of people in the j-th building. Calculated as follows:

$$P_j = U_T + H_j$$  \hspace{1cm} (5)$$

The building carbon footprint deviation rate is:

$$\text{Carbon footprint deviation(%) } = \frac{U_T - \text{Evaluation reference value}}{\text{Evaluation reference value}} \times 100\%$$  \hspace{1cm} (6)$$

$$\text{Carbon footprint score } = 1 - \text{Deviation rate}$$  \hspace{1cm} (7)$$

This article believes that different evaluation levels should match the corresponding carbon footprint level, otherwise the evaluation level should be revised. The revised evaluation method is shown in Table 5.
Table 3. Evaluation level correction table.

| Carbon footprint level | Carbon footprint score | Rating   |
|------------------------|------------------------|----------|
| Level 1                | >1.2                   | Excellent|
| Level 2                | 1.0-1.2                | Good     |
| Level 3                | 0.8-1.0                | General  |
| Level 4                | <0.8                   | Disqualified|

4. Conclusion
Based on the study of the evaluation models of new buildings at home and abroad, this paper builds a new building evaluation model. In this paper, the needs of low-carbon development are considered, the carbon footprint theory is introduced, and the evaluation level of new buildings is revised based on the carbon footprint score to establish an evaluation model. It is hoped that the research in this paper can provide reference and reference for the scientific and reasonable evaluation of new buildings, so as to carry out targeted planning and construction of new buildings.

References
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