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Research and Exploration of Green Building Based on the Basic Theory of Urban Development

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ABSTRACT: Firstly, the influence of building design factors on building carbon emissions was analysed, and the influence of building form factor, building orientation and building envelope on building carbon emissions was simulated and studied, which shows that the south-facing direction has the lowest building carbon emissions, the external window shading factor is negatively related to building carbon emissions, and all other factors are positively related to building carbon emissions. The existing low carbon evaluation systems were then analysed, most of which suffer from a lack of carbon emission calculation methods and a lack of comprehensive scoring methods. This paper establishes an evaluation index system based on the principles of evaluation system construction, determines the benchmarks for index evaluation based on energy saving standards and research data, delineates the range of evaluation index parameters and the percentage of scores, and establishes an evaluation index system. The weights of the evaluation indicators were calculated using hierarchical analysis and combined with expert questionnaires, and a comprehensive scoring method was established based on the weights to build a building carbon emission evaluation system.

1. INTRODUCTION

The fifth report of the United Nations Intergovernmental Panel on Climate Change (IPCC) states that atmospheric concentrations of carbon dioxide began to increase gradually since 1850, and that by 1950 the rate of increase began to accelerate [1]. Rising concentrations of greenhouse gases are causing significant climate change, with greater or lesser impacts on all species on the planet (Bi,2017) [2]. In response to current climate change, many organisms have been forced to change their habitats, migration routes, activity patterns, etc. The human factor plays a large part in this outcome today. Humanity must therefore start taking steps to change this situation. The global community should start with a common climate agreement and work together with major developed countries to address global climate change (Ji,2017) (Liao,2018).

2. SELECTION AND REFINEMENT OF EVALUATION INDICATORS

2.1. Principles of evaluation indicator system construction

To carry out the evaluation of building carbon emissions, it is first necessary to establish a system of evaluation indicators [3], which should be constructed in a comprehensive and scientific manner and be able to evaluate the building design in a comprehensive manner, and therefore the following principles have been established: (1) the principle of systematicity; (2) the principle of scientificity; (3) the principle of operability and comparability (Ma,2021).

2.2. Refinement of evaluation indicators

For the analysis of the factors influencing the carbon emissions of buildings, the architectural design factor is more important among the factors influencing the carbon emissions of buildings at the architectural design stage, and it is more feasible to optimize the architectural design factor [4]. Therefore, this study selects architectural design factors as evaluation indicators, and selects 10 evaluation indicators from two aspects: building shape and building envelope, building orientation, exterior wall heat transfer coefficient, roof heat transfer coefficient, exterior window heat transfer coefficient, exterior window shading coefficient, south-facing window-to-wall ratio, north-facing window-to-wall ratio [5], west-facing window-to-wall ratio and east-facing window-to-wall ratio (Wang,2018).

2.2.1. Building form factor

According to the energy saving standard, the maximum value of the building form factor is 0.4. By analyzing the data of the researched buildings, as shown in Figure 1, the

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maximum value of the building form factor is 0.43, the minimum value is 0.11 and the average value is 0.27, most of them are between 0.2 and 0.33, so the index range of the building form factor is from 0.1 to 0.2, 0.2 to 0.33, 0.33 to 0.4. ,0.33~0.4. Building carbon emissions are positively correlated with building bulk factor, so the larger the building bulk factor, the larger the building carbon emissions, and the lower the low carbon score for the building bulk factor indicator should be, with each range of building bulk factor indicators scoring 100%, 80% and 60% of the total score, as shown in Table 1. The following section assigns scores to indicator ranges with reference to this scoring methodology (Wu,2021).

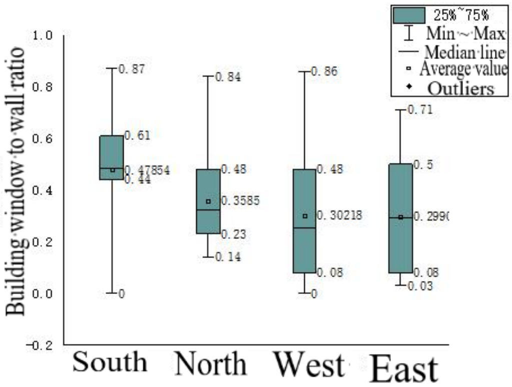

Figure 1. Distribution of building form factors in research cases

Table 1. Building form factor indicator benchmark

Parameter range	Percentage of total mark for the item
0.33~0.4	60%
0.2~0.33	80%
0.1~0.2	100%

2.2.2. Building orientation

According to the energy efficiency standards, the maximum window-to-wall ratio is set at 0.7 for all building orientations. An analysis of the research data is shown in Figure 2. The south-facing window-to-wall ratio is higher than the other orientations because the south-facing side is the main sunrise side, which increases the natural light of the building and requires an increase in window area, so a minimum limit of 0.3 is set for the south-facing window-to-wall ratio. The north-facing window-to-wall ratio is slightly higher than the west- and east-facing window-to-wall ratios. Based on the results of the data analysis shown in Figure 2, the range of window-to-wall ratio indicators and scoring benchmarks for each orientation of the building (Xu,2018).

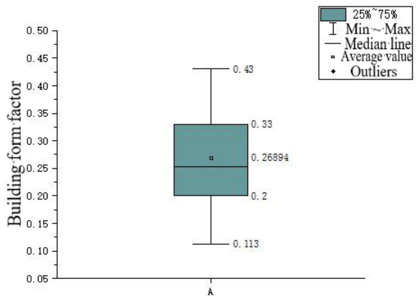

Figure 2. Distribution of window-to-wall ratios by orientation in the building case

2.2.3. Heat transfer coefficient of the roof

In the energy-saving standards, it is stipulated that when the building body coefficient is 0.30 < body coefficient ≤ 0.50, and when the body coefficient of public buildings in cold areas is ≤ 0.3, the maximum value of the roof heat transfer coefficient is $0.45\, W/(m^2 \cdot K)$. Analysis of the research data, as shown in Figure 3, the maximum value of the building case roof heat transfer coefficient is $0.75\, W/(m^2 \cdot K)$, the minimum value is $0.25\, W/(m^2 \cdot K)$, the average value is $0.49\, W/(m^2 \cdot K)$, and most of them are between 0.37 and $0.58\, W/(m^2 \cdot K)$, so the index range of the building roof heat transfer coefficient is shown in Table 2.

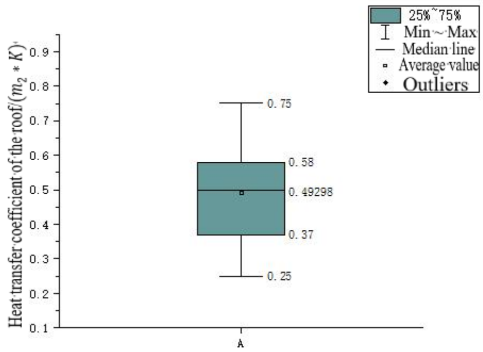

Figure 3. Distribution of heat transfer coefficients in building case roofs

Table 2. Indicator benchmark for heat transfer coefficient of roofing

Parameter range	Percentage of total mark for the item
0.45~0.58	60%
0.37~0.45	80%
0.25~0.37	100%

2.2.4. Whole life cycle carbon intensity of buildings

The whole life cycle carbon intensity of a building refers to the amount of carbon dioxide equivalent emitted per unit of floor space per year (Xiao,2018). Lin Borong conducted a study on the carbon emissions of buildings in China. The results of the study show that the carbon intensity of heating in the north is $37kgCO_2/m_2$, and the carbon intensity of public buildings (except for heating in the north) is $51kgCO_2/m_2$, so the carbon intensity benchmark for public buildings in cold regions is set at $88kgCO_2/m_2$. The General Specification for Energy

Conservation and Renewable Energy Use in Buildings stipulates that the carbon intensity of buildings should be reduced by an average of 40% on basis of the energy efficiency design standards implemented in 2016, respectively, and that the carbon intensity should be reduced by more than $7kgCO_2/m_2$ on average. Therefor a reduction in carbon intensity of $7kgCO_2/m_2$ or more is a higher baseline limit and an increase in carbon intensity of $7kgCO_2/m_2$ or more is a lower baseline limit. The range of indicator benchmarks for the whole life cycle carbon intensity of buildings is shown in Table 3.

Table 3. Benchmarking of life-cycle carbon intensity indicators for buildings

Range of carbon intensity of building emissions[$kgCO_2m^{2*}a$]	**Percentage of total mark for the item**
>95	60%
81~95	80%
<81	100%

3. CALCULATION OF EVALUATION INDICATOR WEIGHTS

Hierarchical analysis is used for decision making on complex problems, mainly by constructing a hierarchy of problems and combining it with the experienced knowledge of professionals to obtain the optimal solution to that decision problem (Zhu,2020) [6].

3.1. Construction of the judgment matrix

The hierarchical analysis method follows the systematic idea of decomposition followed by synthesis [7]. Firstly, the problem needs to be decomposed and a hierarchical analysis model consisting of various influencing factors needs to be constructed. In this study, the building carbon emission evaluation system is divided into a target level, guideline level and an indicator level [8]. The target level is the evaluation of building carbon emissions; the criterion level is the building form, building envelope and building carbon emissions; and the indicator level is the selected factors influencing building carbon emissions. The specific structural hierarchy is shown in Figure 4.

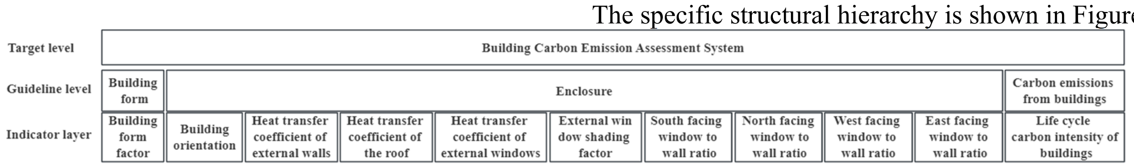

Figure 4. Hierarchy of evaluation systems

3.2. Calculation of the weight vector

Only one eigenvalue of the judgment matrix is non-zero, the rest are zero, so this eigenvalue is the maximum eigenroot, expressed by λ_{max}, and the value of λ_{max} is n, the corresponding eigenvector is w. After normalizing this eigenvector is the weight value of each element, this study uses this method to solve for the weight, using the following formula:

$$Cw = \lambda_{max} w \tag{1}$$

Normalize the elements in the judgment matrix C by column, i.e., find

$$\bar{c}_{kj} = \frac{c_{kj}}{\sum_{k=1}^{n} c_{kj}}, i,j = 1,2,\cdots,n \tag{2}$$

Add up the columns of the same row of the normalized matrix, i.e.

$$\widetilde{w}_i = \sum_{j=1}^{n} \bar{c}_{kj}, i,j = 1,2,\cdots,n \tag{3}$$

The weight vector is obtained by dividing the summed vector by n, i.e.

$$w_i = \widetilde{w}_i / n \tag{4}$$

The maximum characteristic root is calculated as

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n} \frac{(Cw)_i}{w_i} \tag{5}$$

where $(CW)_i$ denotes the ith component of the vector Cw. () denotes the i-th component of the vector Cw.

4. METHODOLOGY FOR EVALUATING CARBON EMISSIONS FROM BUILDINGS

According to the evaluation system, the level of carbon emissions of the building design needs to be scored comprehensively and the building design needs to be evaluated from an overall perspective [9]. Comprehensive scoring generally requires calculations using mathematical models, which are the most essential feature of a set of evaluation criteria, and different mathematical models determine different frameworks of evaluation criteria [10]. This study is oriented towards new low-carbon buildings with clear indicator weights, so the weighted linear sum method is chosen as the mathematical model of the evaluation system, so that the evaluation value of each indicator is transformed into a final score value, which is used to indicate the carbon emission level of the building, and the calculation formula is as follows:

$$x = \sum_{j=1}^{3} * \sum_{i=1}^{n} w_j * w_{ij} * x_{ij} \tag{6}$$

j represents the type of indicator category; i represents the number of indicator items within the category, w_j represents the weighting factor of indicator category j; w_{ij}represents the weighting factor of indicator item i in indicator category j; x_{ij} represents the score of indicator item i.

5. CONCLUSION

Based on the principles of the evaluation system, a total of 11 evaluation indicators were selected from the building body level, the building envelope level and the building carbon emission level, and the evaluation indicators were refined according to the analysis of the building case study data and the provisions of the energy-saving design standards, the benchmarks of the evaluation indicators were established and the parameters of the evaluation indicators were defined. Then, the hierarchical analysis method was used to construct a hierarchical analysis model, and the degree of importance among the evaluation indicators was obtained by means of a questionnaire survey to experts, a judgment matrix was constructed, and the indicator weights were calculated by the characteristic root method. Finally, the evaluation system of building design carbon emission is constructed according to the evaluation index system and index weights, and the comprehensive scoring method of building carbon emission and the corresponding grade standard of the corresponding score are proposed.

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