Evaluation of Student Dormitory Design Programs in Universities

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Abstract. Student dormitory is an important place for students' daily life and study, and its design and construction have an important impact on students' physical and mental health and learning effect. Therefore, the evaluation of student dormitory design programs is particularly important. In this paper, we take economy, comfort and safety as the core evaluation dimensions, construct an evaluation system containing nine indicators, including construction cost, operation cost, fee, per capita area, lighting and ventilation, evacuation, and burglary prevention, and use hierarchical analysis to quantitatively evaluate four typical student dormitory design solutions. By establishing hierarchical model, constructing judgment matrix, and conducting consistency test, the weights of each index are calculated and scored comprehensively. The results show that Scheme 4 is outstanding in terms of safety (shortest evacuation time, highest anti-theft index) and comfort (largest per capita area, optimal ease of use), and has the best comprehensive performance despite higher operating costs; Scheme 2, 3, and 1 are the next best. The study provides a scientific basis for the optimization of student dormitory design scheme, which can effectively improve the living quality and management efficiency of the dormitory.

Keywords: Hierarchical analysis; Evaluation; Optimization; Economy; Comfort; Safety

1. Introduction

As an important part of the infrastructure of higher education, student dormitory is the core space for students to live, study and socialize during their school years, and the quality of its design is directly related to students' physical and mental health, learning efficiency and campus life satisfaction. With the development of higher education and the diversification of students' needs, dormitory design is no longer limited to the simple "residential function", but needs to achieve a dynamic balance between economy, comfort and safety - to control the construction and operation costs, and to meet the students' demand for convenience, but also to ensure the safety and reliability of the living environment.

In foreign countries, the design of student dormitories in colleges and universities focuses on diversification and humanization, rich in types, equipped with complete functional space and service facilities [1], and attaches importance to the creation of communication space and personal space privatization [2], such as European and American colleges and universities, mostly using the model of living room plus bedroom suite to promote student communication. Early domestic dormitory construction focuses on quantity but not quality, and nowadays, although there are improvements, there are still problems such as insufficient service facilities, lack of humanization, monotonous environment, etc.[3], for example, some college dormitories have a small storage space, dull layout, and traditional decorations.

2. Current Problems

At present, the evaluation of student dormitory design solutions mostly relies on empirical judgment or single-dimension analysis [4], and lacks a systematic quantitative assessment framework [5], which makes it difficult to comprehensively reflect the integrated advantages and disadvantages of different solutions. For example, some solutions may be prioritized due to low construction costs [6], but neglect problems such as insufficient lighting [7] or evacuation difficulties; others lack feasibility due to high fees despite outstanding comfort [8]. For this reason, this paper takes four typical student dormitory design schemes as the research object, constructs a multi-indicator evaluation model based

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on hierarchical analysis method (AHP), and quantitatively analyzes the three dimensions of economy (construction cost, operation cost, charging standard), comfort (per capita area, ease of use, lighting and ventilation), and security (evacuation, anti-theft), with the purpose of providing a scientific preference for university dormitory design schemes with a theoretical basis and practical guidance. The purpose is to provide a theoretical basis and practical guidance for the scientific selection of university dormitory design options, and ultimately realize the "cost-controllable, comfortable, safe and reliable" goal of student dormitory construction.

3. Construction of Hierarchical Analysis

3.1 Subject of This Study. This study takes four common buildings with different architectural styles as an example, and constructs a multi-indicator evaluation model based on AHP to analyze them from the three dimensions of economy, comfort and safety, and the four architectural styles are shown below Table 1:

Table 1 Four dormitory design options

	construction area (㎡)	Rooms(room)	Number of students(person)	Bedrooms(㎡)	Bathroom(㎡)	bathrooms (㎡)	Fun rooms(㎡)
Pro. 1	877.35	23	184	25.5	25.52	27.52	/
Pro. 2	2660	55	220	25	28	27.7	115.8
Pro. 3	2229	38	228	26.9	17.2	21.2	/
Pro. 4	1886.64	22	132	52.5	3.6	4.32	/

3.2 Assessment of Individual Indicators in Different Dimensions. By estimating the two-dimensional floor plan and various indicators of the university's design, it can be concluded that: the construction cost per square meter is 1,700 m^2, and the operating cost includes: the salary of the management personnel (assuming 2,790 yuan per person per month), the electricity cost (36 yuan per dormitory per month) and the fixed energy consumption (3,000 yuan per month); and the total charge is calculated according to the number of students based on the benchmark of 112 yuan per student per month for the accommodation fee. Per capita area is derived from the ratio of floor area to the number of dormitory occupants; ease of use is measured by the ratio of common area to the number of students; balcony area is used as the core indicator to assess the effect of natural lighting and air circulation. The evacuation of people needs to consider the evacuation area, staircase capacity and evacuation time in case of emergency; the anti-theft index needs to synthesize the design of doors and windows, monitoring configuration and other factors to quantify the anti-theft ability of the dormitory. From this, the treatment value of each index can be derived:

Table 2 Assessment of indicators in the three dimensions

	D1[￥]	D2[10,000￥]	D3[month]	D4[㎡]	D5	D6	D7[㎡]	D8[min]	D9
Pro.2	1491495	81.46	3427	4.77	0.44	0.39	4.42	2.37	69
Pro.2	4522000	86.05	3360	12.1	1.45	0.78	14.4	1.22	110
Pro.2	3789300	80.34	3615	9.78	2.01	0.56	2.06	0.84	109
Pro.2	3207288	95.55	2352	14.3	3.28	1.09	0	0.53	131

Because of the large differences in the scale and value range of different indicators, direct analysis will be dominated by large-value indicators. Normalization can eliminate the influence of the scale, so that the indicators are in the same order of magnitude, which is convenient for fair comparison, modeling and analysis, and improves the scientific nature of data mining and decision-making. Normalization of the data in Table 2 yields.

Table 3 Normalization of indicators

	D1[￥]	D2[10,000￥]	D3[month]	D4[㎡]	D5	D6	D7[㎡]	D8[min]	D9
Pro.1	0	0.073	0.851	0	0	0	0.307	1	0
Pro.2	1	0.375	0.798	0.769	0.356	0.557	1	0.375	0.665
Pro.3	0.758	0	1	0.526	0.553	0.243	0	0.169	0.654
Pro.4	0.566	1	0	1	1	1	0	0	1

3.3 Construction of Hierarchical Analysis. There are many factors affecting the good and bad of the student dormitory design program, the famous American operations researcher T. L. Saaty in the early 1970s proposed the hierarchical analysis method AHP (analytical hierarchy process) [9] is to quantify the subjective judgment of the human being with a scale, a simple and practical multi-objective decision-making quantitative analysis of qualitative problems. method. We can turn the evaluation problem of student dormitory design scheme into the ranking problem of the relative importance of each factor in the hierarchy to the upper factors, take the comparative judgment of pairs of factors in the ranking calculation, and according to a certain ratio scale, form the judgment matrix, calculate the weight of each factor, and reasonably evaluate the design scheme of student dormitory.

Suppose there are n target bodies, denoted as C_1、$C_2 \cdots C_n$, whose same class attributes are D_1、$D_2 \cdots D_n$.

The AHP decision-making method consists of the following steps:

3.3.1 Modeling of Hierarchical Structures. The elements contained in the problem are grouped and each group is treated as a hierarchy, arranged in the order of goal, criterion, sub-criterion, and programmatic layers. Assessment of the resulting changes serves as model validation. As shown in Fig. 1 :

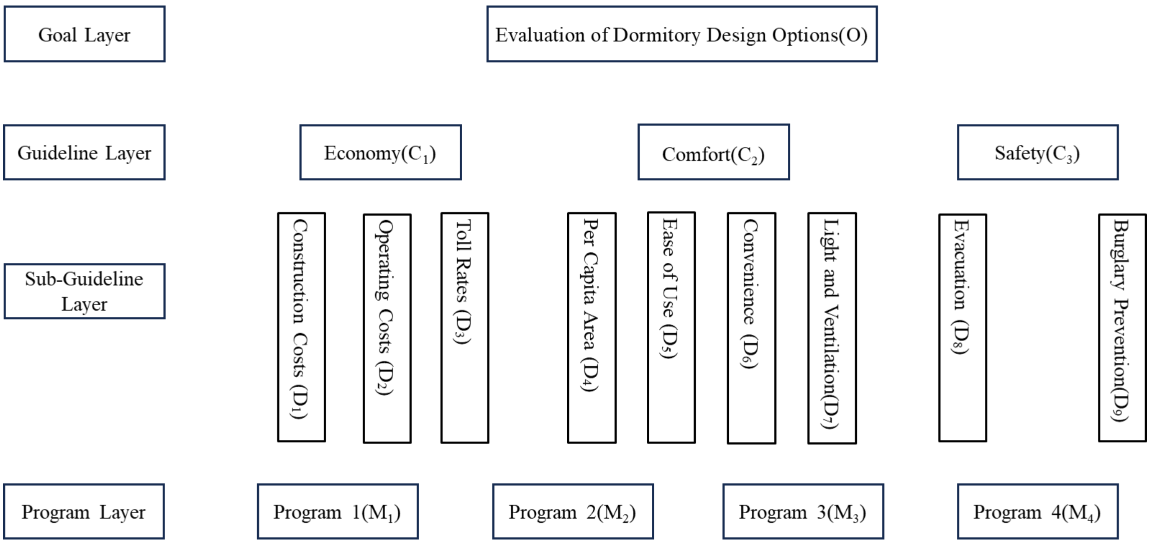

Figure 1. Schematic diagram of the hierarchical model

3.3.2 Construct Judgment Matrix. The judgment matrix element values reflect people's perception of the relative importance of the factors, usually using 1-9 and its reciprocal scale, corresponding to the judgment scale in Figure 2. If the importance of the intercomparison of factors can be illustrated by the ratio of the practical significance of the judgment matrix corresponding to the value of the value can be taken as the ratio [10].

Table 4 Definition of Judgment Scales

Judgment Criteria	Meaning
1	D_i and D_j are equally important
3	D_i and D_j are slightly important
5	D_i and D_j are clearly important
7	D_i and D_j are Strongly Important
9	D_i and D_j are extremely important
2,4,6,8	Intermediate between the above two adjacent judgment scales

Judgment matrices are constructed from different indicators in the three dimensions of economy, comfort and safety as the core evaluation. This is shown in Table 5:

Table 5 Construction of judgment matrix

C	D_1	D_2	D_3	D_4	D_5	D_6	D_7	D_8	D_9
D_1	1	2	3	1/4	1/3	1/2	1/5	1/7	1/6
D_2	1/2	1	2	1/5	1/4	1/3	1/6	1/8	1/7
D_3	1/3	1/2	1	1/6	1/5	1/4	1/7	1/9	1/8
D_4	4	5	6	1	2	3	1/2	1/4	1/3
D_5	3	4	5	1/2	1	2	1/3	1/5	1/4
D_6	2	3	4	1/3	1/2	1	1/4	1/6	1/5
D_7	5	6	7	2	3	4	1	1/3	1/2
D_8	7	8	9	4	5	6	3	1	2
D_9	6	7	8	3	4	5	2	1/2	1

3.3.3 Hierarchical Single Ordering and Consistency Tests. Whether the judgment matrices of each layer structure are reasonable, i.e., whether the experts' evaluations are logically consistent, needs to be measured by a consistency index. According to matrix theory, the sufficient condition for an n-order inverse matrix to have consistency is that its maximum eigenvalue λmax is n. When n is large, the maximum eigenvalue of the judgment matrix A and the corresponding eigenvector W can be calculated according to the following method, which is the ranked weight of the corresponding factor at the same level with respect to the relative importance of a certain factor at the previous level after normalization. The maximum value of λmax is 9.401394, in order to carry out the consistency test of the one-time single ranking (or judgment matrix), it is necessary to calculate the consistency index as CI,which is calculated as follows:

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{1}$$

CR is the consistency ratio, which is an indicator of the consistency of judgment matrix in hierarchical analysis method, and can be calculated from the judgment matrix, and its calculation formula is:

$$CR = \frac{CI}{RI} \tag{2}$$

If CR<0.10, then the evaluation made by the judgment matrix A is reasonably compatible, otherwise it is necessary to adjust the value of the elements of the judgment matrix, the average consistency index table [11] is shown below:

Table 6 Average consistency indicators

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.89	1.12	1.24	1.32	1.41	1.49	1.51

3.3.4 Hierarchical total sorting and consistency test. After the hierarchical single sorting, the relative importance weights for calculating all the factors at the same level for the highest target level are further calculated according to the AHP theory. The sorting weights of the factors at the previous level are weighted to summarize the single sorting weights of the factors at the next level. If the previous level C contains n factors $C_1, C_2, \cdots, C_n$. its hierarchical sorting weights were $C_l, C_2, \cdots, C_n$, the next level contains m factors $D_l, D_2, \cdots D_n$, they are for the factor C_j hierarchical single-ranking weights were D_{1j}, D_{2j} ... ... Dmj At this point, the D level of total importance of all the factors of the highest target level. .Dmj At this time, the total ranking weights of D level are:from $\sum_{j=1}^{n} C_j D_{1j}$ to $\sum_{j=1}^{n} C_j D_{nj}$.

Consistency test: If the corresponding average stochastic consistency indicator CI_j of certain factors of level D for the single ordering of level C is RI_j, then the formula for the total ordering stochastic consistency ratio of level D is:

$$CR = \frac{\sum_{j=1}^{n} c_j CI_j}{\sum_{j=1}^{n} c_j RI_j} \quad (3)$$

Consistency test was performed and satisfactory consistency was obtained with CI=0.050174, RI=1.449990, CR=0.034603<0.10.

3.3.5 Assessment of importance ranking weights for design options for dormitories

The core code is as follows:

```
% Compute eigenvalues and eigenvectors
[V, D] = eig(A);
% Find the eigenvector corresponding to the largest eigenvalue
[maxEigenvalue, maxIndex] = max(diag(D));
weights = V(:, maxIndex);
% Normalize the feature vectors to get the weights
weights = weights / sum(weights);
% Display weights
disp(' Importance weight： ');
disp(weights);
```

Table 7 Ranking of indicator weights at the sub-criteria level

Parameters	Sorting	Weights
D_8	1	0.3121
D_9	2	0.2223
D_7	3	0.1555
D_4	4	0.1075
D_5	5	0.0739

D_6	6	0.0507
D_1	7	0.0350
D_2	8	0.0247
D_3	9	0.0183

4 Summary

This paper establishes a model through hierarchical analysis, and evaluates the model from three aspects of economy, comfort and safety. Considering from the aspect of safety: the evacuation time of Option 4 is the least, and the evacuation time of Option 1 is the longest; from the aspect of burglary prevention, we can see that the burglary prevention ability of Option 1 is the worst, and the burglary prevention ability of Option 4 is the best. Considering from the perspective of comfort: Option 1 has the worst experience in terms of “area per capita”, “ease of use” and “non-interference”, while Option 4 has the opposite; from the perspective of “lighting and ventilation”, Option 4 has the worst experience. In terms of “light and ventilation”, shows that Option 2 has the highest indicators, while Options 3 and 4 have the lowest indicators. From the economic aspects of to consider: according to the “construction cost” aspect: the cost of Option 1 is the lowest, the cost of Option 2 is the highest; according to the “running cost” factor, the running cost of Option 3 is the lowest, the running cost of Option 4 is the highest; from the “fee standard” aspect: the cost of Option 2 is the lowest, the cost of Option 4 is the highest. According to the factor of “fee standard”, Option 3 has the highest fee and Option 4 has the lowest fee cost.Through comparison, the best option is option 4, followed by option 2, option 3, option 1, of which option 4 is the best in terms of economy, comfort and safety.

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