Research on Energy-Saving Renovation of College Existing Building Based on Value Engineering

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Abstract. Through the principle of the Value Engineering, this article chooses the college existing buildings which need for energy saving renovation. This article analyzes the building function from four aspects: the roof engineering, the walls engineering, the door and window engineering, the heating network renovation engineering. It calculates the cost of the whole life cycle construction, and establishes an evaluation model. Then, it verifies the validity of the model through the boiler room renovation project in our school.

1. Introduction
With the increasing depletion of global energy, energy saving has become a global problem that needs to be solved urgently. Building energy saving is one of the most important energy-savings areas. With the increasing shortage of college students, the strategic mode of campus expansion is coming to an end, and the proportion of reconstruction projects is increasing. Compared with the newly-built projects, the reconstruction projects of colleges have the characteristics of small scale, short construction period, low investment and high customization. Therefore, how to reduce the construction cost under the premise of satisfying the function is particularly important.

At present, some achievements have been made on the reconstruction of existing buildings in colleges, but mainly from the aspect of cost control. The theory of Value Engineering is used to calculate the cost of reconstruction from the whole life cycle in the retaining structure. It analyzes the existing buildings from the roof engineering, the wall engineering, the door and window engineering, the heating network energy saving renovation of four aspects to choose cost-effective design.

2. Basic Theory of Value Engineering
Value Engineering(VE) is also known as Value Analysis(VA). It is a technology method of system analysis which designs the users’ necessary functions through the lowest cost of the whole life cycle.

And it also analyses the cost of the product.
The formula is: \( V = \frac{F}{C} \)
Where: \( V \) - value; \( F \) - the function; \( C \) - the cost or expense.

The main idea of Value Engineering is to improve the value of the selected research object by analyzing the function and the cost of the selected research object or to select the optimal scheme from many schemes.

3. Evaluation Model

3.1 Select the Analysis Object
According to the existing research data, this article analyzes the existing buildings that need to be energy-saving renovation in colleges from two aspects.

3.2 Functional System Analysis

(1) draw functional system diagram

According to the existing research results, this article selected the maintenance structure with high energy consumption in the existing buildings in colleges. It analyzes the main object of energy-saving transformation and draws an functional system diagram (Figure 1).

1) wall engineering: As the wall engineering with the largest proportion of heat dissipation in the building, it is the focus of energy-saving transformation. The exterior walls of buildings decades ago have energy-saving measures. Therefore, the exterior walls should be modified with more energy-saving materials such as rock wool board and benzene board, which should be firmly fixed and waterproof measures should be taken.

2) roofing construction: The original building part without energy saving measures, therefore, it should increase extruded polystyrene board on the roof or expanded perlite board insulation materials, such as adding building insulation.

3) door window project: The transformation of door window project mainly includes two aspects: For one thing, we should choose window frame with better material and hollow glass, so as to improve the quality of windows and doors. For another thing, attentions should be paid to handle the gap between windows and walls, as far as possible with foaming agent, rock wool board to reduce the gap between doors and windows in order to reduce heat losses.

4) the heating pipe network transformation: As the number of years is longer, the original building heating pipeline aging, therefore, you need to modify or outdoor pipe network damage replacement heating system, and at the entrance of the thermal heat meter installation in order to meter the heat.

3.3 Functional Evaluation

At the design stage, two or more schemes should be proposed for comparison and selection, and the weight of each evaluation index should be determined.

(1) determine the functional weight

The 0-4 scoring method is used to get the functional weight. 5-15 people who were familiar with the design scheme were asked to rate according to the four grades: \( F_1 \) was much more important than \( F_2, F_1 \) got 4 points and \( F_2 \) got 0 points. \( F_1 \) is more important than \( F_2, F_1 \) got 3 points and \( F_2 \) got 1 points. \( F_1 \) is as important as \( F_2, F_1 \) got 2 points and \( F_2 \) got 2 points. \( F_1 \) was less important than \( F_2, F_1 \) got 1 points and \( F_2 \) got 3 points.

First, we should score each one according to the functional importance, and fill it in the form of matrix. The object to be analyzed does not score as compared with itself, in the form of "×". Finally, according to the functional importance coefficient \( W_i \) obtained by each participant's selection of the
component, the average value of the functional importance coefficient $W$ of the component can be obtained.

$$W = \frac{\sum_{i=1}^{k} W_i}{k}$$

Where: $k$ -- the number of participants in functional evaluation.

(2) calculate the functional coefficient

According to the function score and weight of each scheme by 10-point function evaluation, each function weighted score multiplied by the weight function. The scheme of each function weighted points together, the function of alternative weighted and then puts the function of each scheme weighted points out all solution function weighted points total, total scores and all the function of the weighted coefficient of the ratio of the scheme is function.

The calculation formula is: Functional Coefficient $F_i = \frac{\text{the sum of the total score of a program's function evaluation}}{\text{the total score of each program's function evaluation}}$.

(3) calculate the cost coefficient

According to the scheme provided by the unilateral cost and the use cost of each year, according to the benchmark yield its discount, we can calculate the cost present value of each scheme. Add up the project cost present value addition to arrive at a total cost present value, total cost present value and the ratio of the sum of each project cost present value is the cost coefficient.

The calculation formula is: the cost coefficient of each scheme $C_i = \frac{\text{the sum of the cost per side of each scheme}}{\text{the cost per side of each scheme}}$.

(4) calculate the value coefficient

Calculate the value coefficient according to the function coefficient and cost coefficient of each scheme.

The calculation formula is: $Vi = \frac{\text{functional coefficient (F_i) \times cost coefficient (C_i)}}{\text{cost coefficient (C_i)}}$.

(5) options

Because coefficient shows that the higher the ratio of value, therefore, it should be the value coefficient of $V > 1$ solution as a selection object. Finally, we choose the plan with maximum value coefficient as the preferred object.

4. Case Application

The original boiler room of our school is a frame structure with three partial floors. Now according to the requirements of the school, it will be transformed into the laboratory of the Art College. Part of the renovation is the original boiler room, and the rest of the equipment room will not be renovated. The area of each floor is about 800m$^2$, and the total area of three floors is 2400m$^2$. The building practice of the former boiler room is: the exterior window is a single-layer glass plastic steel window, and the roof surface is 1:6 cement coke slag to find slope after 100 thick precast perlite board, there is no insulation practice on the outer wall. Two existing energy-saving design schemes are available for selection. How should we choose the plan. (assume the service life after the reconstruction is 30 years, and the benchmark yield is 8%)

4.1 Project Overview

Solution A: An increase of 100mm rock wool board wall thermal insulation, all replacement for the broken bridge aluminum alloy double vacuum window outside doors and windows, roof insulation uses 80mm extruded polystyrene board, all for indoor heating pipe network transformation, dismantled and increase the flow meter, unilateral cost is RMB 1700 per m$^2$, operation cost is RMB 2500 each year.

Solution B: An increase of 100mm benzene board wall thermal insulation, outside doors and windows all replacement for double vacuum insulation window, and equipped with thermal insulation curtain, roof insulation use 80mm expanded perlite board, only for indoor heating pipe network to
repair damaged parts, without increasing the flowmeter, unilateral cost is RMB 1600 per m², operation cost is RMB 3000 each year.

4.2 Functional Evaluation

(1) establish the functional system diagram as shown in figure 1, and apply 0-4 scoring method to determine the weight of each evaluation index as shown in table 1.

| The evaluation index               | Exterior wall project F₁ | Roofing construction F₂ | Doors and Windows project F₃ | Heat supply network renovation F₄ | Score | The weight |
|------------------------------------|--------------------------|-------------------------|-------------------------------|----------------------------------|-------|------------|
| Exterior wall project F₁           | ×                        | 2                       | 3                             | 4                                | 9     | 0.38       |
| Roofing construction F₂            | 2                        | ×                       | 2                             | 3                                | 7     | 0.29       |
| Doors and Windows project F₃       | 1                        | 2                       | ×                             | 3                                | 6     | 0.25       |
| Heat supply network renovation F₄  | 0                        | 1                       | 1                             | ×                                | 2     | 0.08       |

(2) six related personnel were selected to score the two schemes on a scale of ten, and their functional coefficients were determined according to the weight as shown in table 2.

| The Evaluation Index | The weight | Solution A | Solution B |
|----------------------|------------|------------|------------|
| Exterior wall project F₁ | 0.38       | 7.00       | 9.00       |
| Roofing construction F₂   | 0.29       | 9.00       | 9.00       |
| Doors and Windows project F₃ | 0.25       | 8.00       | 9.00       |
| Heat supply network renovation F₄ | 0.08       | 8.00       | 9.00       |
| Function coefficient | 1          | 0.53       | 0.47       |

(3) the cost control of existing construction reconstruction projects in colleges and universities should be conducted from the perspective of the whole process. Besides the construction cost, the use cost should also be considered to determine the reasonable scheme. The cost coefficient of each scheme is calculated, and the results are shown in table 3.

| The cost of unilateral | Solution A | Solution B |
|------------------------|------------|------------|
| 1700                   | 1600       |
| Use cost               | 2500       | 3000       |
| The discount factor    | 11.258     | 11.258     |
| One - way discount cost| 1440.7     | 1614.07    |
| The cost factor        | 0.51       | 0.49       |

(4) calculate the value coefficient of each scheme and select it. The results are shown in table 4.

| Alternative offer | Solution A | Solution B |
|-------------------|------------|------------|
| Function coefficient | 0.53       | 0.47       |
| The cost factor | 0.51       | 0.49       |
| Value coefficient | 1.03       | 0.96       |

Conclusion: According to the principle of Value Engineering, solution A’s value coefficient V>1. Therefore, we should choose solution A as the final scheme of this design, because its cost performance is high.
5. Conclusion

(1) We choose the palisade structure of energy consumption as the research object because it is the highest part. It mainly includes wall engineering, roofing engineering, door and window engineering, heat supply pipeline. It's consistent with the actual situation and the research results is good.

(2) It is difficult to control the cost of existing buildings in colleges because of the particularity of the projects, therefore, we should be more solutions than choose in decision-making stage, design stage should inspire designers design optimization of consciousness, the project construction stage is not optional, carefully check the actual quantity settlement, and from the whole process to reasonable control of project cost, as far as possible to control it in a reasonable range.

(3) Using Value Engineering Principle, this article compare the schemes through the boiler room in our school. According to actual condition selected cost-effective energy-saving retrofit scheme, it can satisfy the use function and reduce cost. However, because of the historical problems such as incomplete original drawing data and inconsistency between the finished drawing and the actual situation, the existing construction reconstruction project in colleges should strengthen the arrangement of completed files, which should be a reliable reference basis in the future.

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