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# Analysis of the Factors Influencing the Cost of Prefabricated Components for Assembled Buildings Based on ISM and AHP

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**Abstract.** The increasing cost of prefabricated components of assembled buildings has hindered the development and promotion of the assembled industry in China, so it is of great practical significance to conduct an in-depth study on the cost influencing factors of prefabricated components of assembled buildings. In this study, the cost influencing factors of prefabricated components are selected as the research object. Firstly, 12 influencing factors are screened through literature research; secondly, the structural model of cost influencing factors is constructed based on ISM and AHP methods, and the influence of each factor is ranked; finally, the influence of factors at all levels on the cost of prefabricated components is analyzed from the surface, intermediate and deep levels respectively according to the comprehensive weights, and the influence of factors on the cost of assembled buildings is proposed. The countermeasures and suggestions for cost control of prefabricated components are proposed.

**Keywords.** Prefabricated components, cost, ISM, AHP, assembly building

## 1. Introduction

In order to implement the development goals of China's new urbanization and building industrialization, relevant places have issued a number of policy documents to promote the development of prefabricated building. Prefabricated building can significantly reduce energy consumption, and effectively improve the quality and environment of the project. However, at present, the system and technical specifications are not perfect. Therefore, the cost of new construction methods is higher than that of traditional construction. Due to the high cost, the market scale of prefabricated building is limited and the overall development speed is slow. Therefore, effective control of the cost of

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prefabricated components in prefabricated building is the key means for the rapid development of prefabricated building in China [1].

Scholars at home and abroad have carried out relevant research on the cost of prefabricated components in prefabricated building, and have achieved certain results. Jin Hao, Li Jinjun and others [2] proposed cost control methods for prefabricated building based on examples from the composition of cost increment; Yu Hai'an, Shang Zufeng and others [3] carried out cost accounting research on prefabricated components of prefabricated building based on TDABC. To sum up, the cost of prefabricated components of prefabricated building is a key factor restricting its rapid development and efficient application. Therefore, it is of practical significance to discuss the degree of influence on the cost of prefabricated parts of prefabricated building.

However, at present, there are few studies on the factors affecting the cost of prefabricated components in prefabricated building in China, most of which are based on a single mathematical model. Therefore, this paper uses ISM and AHP methods to analyze the cost of prefabricated components in prefabricated building, and puts forward corresponding control countermeasures and suggestions.

## 2. Construction of Component Cost Influencing Factor Indicator System

### *2.1. Selection of Influencing Factors*

Firstly, CNKI periodical database and WOS were used as the search platform to search for keywords such as "cost analysis of prefabricated components" and "cost influencing factors". This study considers from the perspective of EPC project general contracting mode, and initially identifies 36 factors that have an important impact on the cost of prefabricated components of prefabricated building in the process of design, production, transportation and construction.

In order to further sort out the core influencing factors that affect the component cost of prefabricated building, after discussion and suggestions of the research expert group, 36 initially determined component cost influencing factors are selected and deleted. After three screening, 12 factors affecting the cost of prefabricated components of prefabricated building with research significance and strong representativeness were finally screened out, as shown in table 1.

**Table 1.** Factors Affecting the Cost of Prefabricated Components After Screening.

| Classify | Encode | Influencing Factor | Classify | Encode | Influencing Factor |
|---|---|---|---|---|---|
| | S1 | Prefabrication rate and assembly rate | | S7 | Load diatance |
| Design | S2 | Degree of component standardization | Transport | S8 | Vehicle scheduling scheme |
| | S3 | Component repetition rate | | S9 | Vehicle loading scheme |
| | S4 | Price of raw material | | S10 | Construction mechanization level |
| Produce | S5 | Production capacity | Construct | S11 | Equipment rental fee |
| | S6 | Die turnover rate | | S12 | Application of BIM technology |

### 2.2. Data Processing and Analysis

In order to determine that the 12 indicators selected in table 2 can be used as the main factors affecting the cost of prefabricated components of prefabricated building, this study use the Likert 5-level scale method, "1" represents slightly important, "2" represents important, "3" represents generally important, "4" represents relatively important, and "5" represents very important.

1) Data Sources and Analysis

In this survey, 25 experts with experience in prefabricated building were invited for scoring. A total of 50 questionnaires were distributed to prefabricated building related practitioners and scientific researchers, but only 26 questionnaires were actually recovered for research and analysis.

2) Data Rationality Testing

In this study, the representativeness of the factors affecting the cost of prefabricated building components and the reliability of the questionnaire setting were tested. The results show that the reliability coefficient Cronback's α, the coefficient is 0.937>0.9, indicating that the reliability and credibility of the questionnaire meet the requirements; The validity coefficient KMO value is 0.872>0.5, indicating good statistical correlation among various influencing factors. Moreover, all indicators are concentrated in 5 effective factors with significantly higher characteristic values than 1, indicating a good aggregation effect between the selected 12 factors.

## 3. Construction of ISM Model for Influencing Factors of Component Costs

Interpretation Structure Model decomposes a system into small subsystems and analyzes the structural changes of complex systems. It is a scientific and effective method for constructing a system structure model [4].

This study used the ISM model to classify the identified four categories and 12 specific factors, and arranged them in sequence numbers $S_1$-$S_{12}$. While vertically reflecting the mutual influence and constraint relationship between factors, it also horizontally elaborates on the correlation relationship of factors, avoiding the subjectivity of expert scoring and weighting, and the risk of model calculation being disconnected from reality [5].

### 3.1. Establish Adjacency Matrix

For the matrix of adjacent relationship between factors, establish the corresponding adjacency matrix $A$. The matrix element $a_{ij}$ refers to the $i$-th and $j$-th elements in $A$, and when $S_i$ has an impact on $S_j$, $a_{ij}$ is 1; When $S_i$ has no effect on $S_j$, $a_{ij}$ is 0 [6], i.e.:

$$A = a_{ij} = \begin{cases} 1, & S_i \text{ has an impact on } S_j \\ 0, & S_i \text{ has no impact on } S_j \end{cases} \quad (i, j = 1, 2, \ldots, 12) \tag{1}$$

This article determines the impact relationship between the cost influencing factors of prefabricated components through a survey questionnaire scoring method, and concludes $S_{12\times 12}$.

### 3.2. Form Reachable Matrix

Establish reachability matrix, i.e.:

$$M = (A+E)^k = (A+E)^{k-1} \neq \cdots \neq (A+E)\,(k \leq n-1) \tag{2}$$

After calculating $k$=4, the reachable matrix $M$ is obtained, as shown in table 2:

**Table 2.** Reachability Matrix.

| $S_i$ | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | $S_6$ | $S_7$ | $S_8$ | $S_9$ | $S_{10}$ | $S_{11}$ | $S_{12}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $S_1$ | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| $S_2$ | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| $S_3$ | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| $S_4$ | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| $S_5$ | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| $S_6$ | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| $S_7$ | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| $S_8$ | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| $S_9$ | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| $S_{10}$ | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| $S_{11}$ | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| $S_{12}$ | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

### 3.3. Dividing Hierarchical Relationships

After the reachability matrix is obtained, the model of factors affecting the cost of prefabricated components in prefabricated building is hierarchically divided. According to $R(S_i) \cap Q(S_i) = A(S_i)$, a new reachable matrix $A(S_i)$ is obtained [7], as shown in table 3.

**Table 3.** Reachable Set, Antecedent Set, and Common Intersection.

| $S_i$ | $R(S_i)$ | $Q(S_i)$ | $A(S_i)$ |
|---|---|---|---|
| $S_1$ | 1,2,3,5,6,7,8,9,10,11,12 | 1,2,3,4,5,6,10,11,12 | 1,2,3,5,6,10,11,12 |
| $S_2$ | 1,2,3,5,6,7,8,9,10,11,12 | 1,2,3,4,5,6,10,11,12 | 1,2,3,5,6,10,11,12 |
| $S_3$ | 1,2,3,5,6,7,8,9,10,11,12 | 1,2,3,4,5,6,10,11,12 | 1,2,3,5,6,10,11,12 |
| $S_4$ | 1,2,3,4,5,6,7,8,9,10,11,12 | 4 | 4 |
| $S_5$ | 1,2,3,5,6,7,8,9,10,11,12 | 1,2,3,4,5,6,10,11,12 | 1,2,3,5,6,10,11,12 |
| $S_6$ | 1,2,3,5,6,7,8,9,10,11,12 | 1,2,3,4,5,6,10,11,12 | 1,2,3,5,6,10,11,12 |
| $S_7$ | 7,8,9 | 1,2,3,4,5,6,7,8,9,10,11,12 | 8,9,7 |
| $S_8$ | 7,8,9 | 1,2,3,4,5,6,7,8,9,10,11,12 | 8,9,7 |
| $S_9$ | 7,8,9 | 1,2,3,4,5,6,7,8,9,10,11,12 | 8,9,7 |
| $S_{10}$ | 1,2,3,5,6,7,8,9,10,11,12 | 1,2,3,4,5,6,10,11,12 | 1,2,3,5,6,10,11,12 |
| $S_{11}$ | 1,2,3,5,6,7,8,9,10,11,12 | 1,2,3,4,5,6,10,11,12 | 1,2,3,5,6,10,11,12 |
| $S_{12}$ | 1,2,3,5,6,7,8,9,10,11,12 | 1,2,3,4,5,6,10,11,12 | 1,2,3,5,6,10,11,12 |

### 3.4. Building an Interpretive Structural Model

Based on the division of each level in table 3, the primary element set $L_1$=[$S_7$, $S_8$, $S_9$] that affects the cost of prefabricated components of prefabricated building; Secondary element set $L_2$ =[$S_1$, $S_2$, $S_3$, $S_5$, $S_6$, $S_{10}$, $S_{11}$, $S_{12}$]; Third level element set $L_3$ =[$S_4$], combined with the above results, a structural model for explaining the factors affecting the cost of prefabricated components is finally obtained, as shown in figure 1.

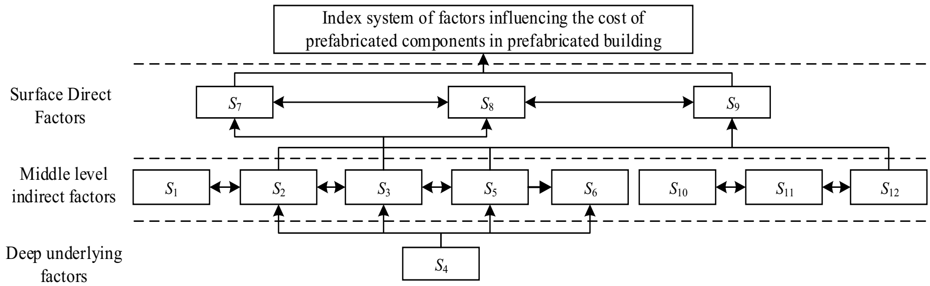


**Figure 1.** Interpretative Structural Modeling.

## 4. Construction of AHP Model for Influencing Factors of Component Costs

ISM is unable to provide specific quantitative results, so it continues to study using the analytic hierarchy process. Analytic Hierarchy Process (AHP) is the process of clarifying complex system problems through qualitative and quantitative analysis [8].

### 4.1. Calculate Indicator Weights

Establishes an indicator system for the factors affecting the cost of prefabricated components, $W_1$-$W_{12}$ = $S_1$-$S_{12}$. Based on the ISM analysis results, the importance of the lower layers to the upper layers in the explanatory structural model is used to score the AHP influencing factor indicator system according to the scoring standards of the scaling method and expert scoring method, and a judgment matrix is constructed [9].

After inspection, the consistency ratio of the judgment matrix is 0.134, which meets the consistency requirements [10]. The calculated indicator layer weights are shown in table 4.

**Table 4.** Weight Summary Table Based on Analytic Hierarchy Process.

| Primary Index | | Secondary Index | | Primary Index | | Secondary Index | |
|---|---|---|---|---|---|---|---|
| Index | Weight | Index | Weight | Index | Weight | Index | Weight |
| | | $W_1$ | 0.179 | | | $W_7$ | 0.059 |
| Design | 0.329 | $W_2$ | 0.117 | Transport | 0.097 | $W_8$ | 0.020 |
| | | $W_3$ | 0.034 | | | $W_9$ | 0.017 |
| | | $W_4$ | 0.327 | | | $W_{10}$ | 0.089 |
| Produce | 0.453 | $W_5$ | 0.083 | Construct | 0.122 | $W_{11}$ | 0.030 |
| | | $W_6$ | 0.043 | | | $W_{12}$ | 0.003 |

### 4.2. Weight Result Evaluation Analysis

From table 4, it can be seen that the proportion of investment in design, production, transportation and construction is 0.329, 0.453, 0.097 and 0.122, which indicates that production accounts for most of the weight in the first level indicators of the cost influencing factors of prefabricated components of prefabricated building; In the secondary indicators, the weight of raw material prices is the highest, followed by prefabrication rate, and assembly rate, with BIM technology application accounting for the least weight.

## 5. Evaluation and Analysis of Weight Results, Calculation Results and Analysis

According to the ISM model established in figure 1, the factors that affect the cost development of prefabricated components in prefabricated building can be divided into three levels, and each level can be directly or indirectly affected, thus having a impact on the cost development of components. Based on the above research, the model structure of influencing factors will be discussed from three levels.

The surface direct influencing factors consist of three elements: transportation distance, vehicle scheduling plan, and vehicle loading plan. The transportation distance affects the transportation cost, and vehicle scheduling and loading plans are related to the efficiency of component transportation.

The indirect influencing factors in the middle are composed of eight factors, including prefabrication rate, and component repetition rate, etc. Improving the repetition rate and standardization of components is the theoretical basis for expanding production scale. The more mold turnover times, the maximum cost reduction in the production process of prefabricated components can be achieved.

The deep-seated fundamental influencing factor is the price of raw materials. National policies and regulations have an impact on the development of the cost of prefabricated components. Providing encouragement and preferential treatment to various industries of prefabricated components and regulating the price range of raw materials can low-cost development of the prefabricated industry be achieved.

## 6. Countermeasures and Suggestions

This research is based on the construction of an interpretative structural model of the factors affecting the cost of prefabricated components in prefabricated building, and the weight of the factors at all levels is evaluated by combining the AHP method. The following suggestions are proposed.

Strengthen the standardization and integrated design of prefabricated components. The government needs to accelerate the establishment of a sound and coordinated industrial chain, and reduce production costs through the standardization of prefabricated components.

Strengthen policy support and promote industry development policies and regulations. Specifically, it is necessary to determine the development goals of prefabricated building in different regions and provide industrial support for prefabricated projects based on the development status of economy and industry.

Introduce advanced technology to improve the level of enterprise informatization. In the production process, the use of information technology improves the turnover rate of molds and the utilization rate of assembly line machines; During the transportation process, the use of BIM+GIS technology can help select and arrange transportation routes, thereby improving transportation efficiency and vehicle utilization.

## 7. Conclusion

This study screened the influencing factors of the cost of prefabricated components from the four aspects of design, production, transportation and construction through literature review and expert scoring. According to the evaluation method of influencing factors, the cost analysis model of prefabricated components of prefabricated building was constructed by combining ISM and AHP. The ISM method was used to classify each influencing factor layer by layer, and the weights of each level of influencing factors were determined using the AHP method. A combination of qualitative and quantitative methods was used to describe the main factors and action paths that affect the cost of prefabricated components. At the same time, the logical relationship between influencing factors was analyzed. Finally, countermeasures and suggestions are put forward, the results are expected to provide a reference for the subsequent cost study of prefabricated building.

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