Cost Factor Analysis of Prefabricated Components Based on Adversarial interpretive structure model Method

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Abstract . The development of prefabricated buildings is restricted by the high cost of prefabricated components to a certain extent, and the cost of prefabricated components is determined by the complex relationship between various factors. In order to clarify the relationship between the factors affecting the cost of prefabricated components, 17 influencing factors were finally determined by querying the literature and visiting experts for screening. By using the adversarial interpretative structural model (AISM) for modeling, a set of directed topological hierarchical graphs with adversarial relationships is obtained. Based on the comparative analysis of different hierarchical graphs, the relationship between various factors is visually displayed. Through analysis, it is found that the fundamental factors affecting the assembly construction cost are policies and regulations, and the direct reasons are component production level, production cost, vehicle scheduling cost and parts stacking place. There is a correlation between these factors, so according to the analysis results, relevant rationalization suggestions are given to reduce the cost of assembled components. In order to play a positive reference significance for the cost management of subsequent assembly components.

Keywords: prefabricated components; cost factors; AISM

1 Introduction

On the study of the cost of prefabricated construction, through early comparative analysis [1-2] of the cost of prefabricated construction and cast-in-place construction, it is found that the cost of prefabricated construction is higher than that of cast-in-place construction, mainly concentrated in the civil construction part. At this time, some researchers have found that the main factor influencing the cost of prefabricated construction is the prefabricated component. The subsequent research begins[3-5] by examining incremental costs and cost control. It then presents a comprehensive unit price list that separates the costs of construction and installation. This analysis concludes that the high cost of prefabricated construction is primarily due to the prefabricated components. On this basis, recent research has employed various methods such as gray correlation analysis, fuzzy comprehensive evaluation, fuzzy TOPSIS method, and interpretive structure model to explore the factors that affect the cost of prefabri-

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cated components. These methods have been applied to the design, production, transportation, and installation of these four main aspects, with the aim of finding ways to reduce the cost of prefabricated components.

The aforementioned research has summarized and analyzed the factors that impact the cost of prefabricated components at each stage. This provides a theoretical and research foundation for future studies on the cost factors of prefabricated components. At present, most research focuses on the influence of a single factor on the cost of assembled components, while ignoring the interrelation between factors at each stage. Therefore, this paper proposes an alternative interpretation structure model (AISM) based on the existing interpretation structure model (ISM). After identifying various factors that influence the cost of assembled components from design to operation, a directed hierarchical topological diagram has been obtained using the AISM model. This diagram shows the relationships between these factors. According to this adversarial topology, it is possible to determine the interaction between these factors and the extent of their influence on the cost of the assembled component. Based on this, it can not only improve research on the influencing factors of the cost of assembled components but also provide a theoretical basis for adjusting management methods to control the cost of assembled components at each stage of the process, from design to implementation. This will help reduce the overall cost of assembled components.

2 Identification of Influencing Factors

On the basis of the existing literature, a literature review and screening were conducted. A total of 9 experts, including those engaged in design, project site management, cost accounting, and construction units, were issued questionnaires. Finally, the factors that affect the cost of prefabricated components are summarized, considering both qualitative and quantitative indicators. The following 17 indicators are summarized.

Table 1. Screening table of influencing factors of assembled components.

First-level indicators	Secondary indicators	Explanatory notes
Design phase	Component splitting rationality[6] [7] [10]	Whether the component is easy to produce and transport, and whether the component splitting is standard
Production stage	Component production technology level[7] [11]	Control the product process and quality
	Component production method[6] [7] [8]	Line work or customized production
	Mold turnover level[8] [10]	The frequency of the same mold turnover
	Production cost[7] [11] [12]	The cost required in the production process
Transportation stage	Vehicle loading rate[9] [10]	actual load mass/ maximum load mass
	Transport distance[6] [9] [11]	Distance from component manufacturing plant to corresponding project site

	Transportation route[8] [9] [12]	Multiple transportation routes need to be compared to choose the most economical route
	Vehicle dispatch cost[7] [8] [10]	Driver salaries, fuel costs, tolls, etc
Installation phase	Management and installation levels[6] [10] [11]	Overall control of the installation process and quality of prefabricated components on the project site
	Selection of hoisting machinery[9] [12]	According to different types of components, choose different sizes of lifting equipment
	Parts stacking place[8] [10]	The installation of accessories requires temporary places to stack
	Component installation sequence[9] [10] [11]	Process and connection and sequence in the process of component installation
External environment	Policies and regulations[6] [7] [12]	The role of policies and regulations on assembly
	Local assembly industry development status[7] [8] [10]	In the development process of the local construction industry, the promotion of the assembly type
	Specifications and Standards[11] [12]	Related specifications and standards for prefabricated components
Others	Application of information technology for prefabricated components[8] [12]	Application of BIM technology in fabricated components

3 Aism Model of Assembled Component Cost Influencing Factors

The System Interpretive Structural Model (ISM), originally proposed by American professor J. Warfield in 1973, is primarily used to analyze the components of complex systems and the relationships between these elements（Table.1）. After completing a specific process operation, a hierarchy diagram can be obtained with the result as the top priority. This hierarchy diagram is organized in a way that forms a multi-level hierarchical system, ultimately resulting in a hierarchy diagram that is focused on achieving results. The essence of the AISM, derived from the Game Interpretation Structure model, is that it combines ISM's outcome-first hierarchy extraction rules with reason-first hierarchy extraction rules, resulting in a set of rival hierarchy topographies. What is the AISM? AISM provides a clear and intuitive view of the relationship between various factors and assesses the strengths and weaknesses of each factor. Owing to different extraction rules, the resulting two rival topographies may not be the same. Horizontal comparison of the two groups of topographies has revealed the structure of influential factors at different levels and their interrelation.

3.1 Draw the Adversarial Topology Hierarchy Diagram

According to the relationship between various factors and the extraction results of the adversarial hierarchy, draw the directed topology hierarchy diagram.

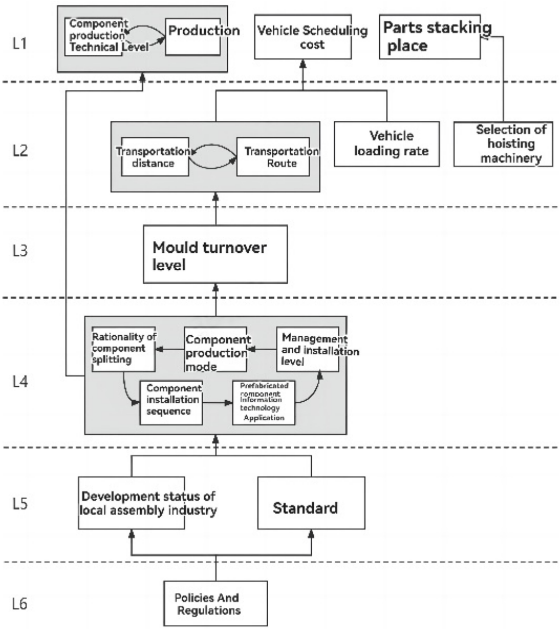

Fig. 1. UP hierarchy topology

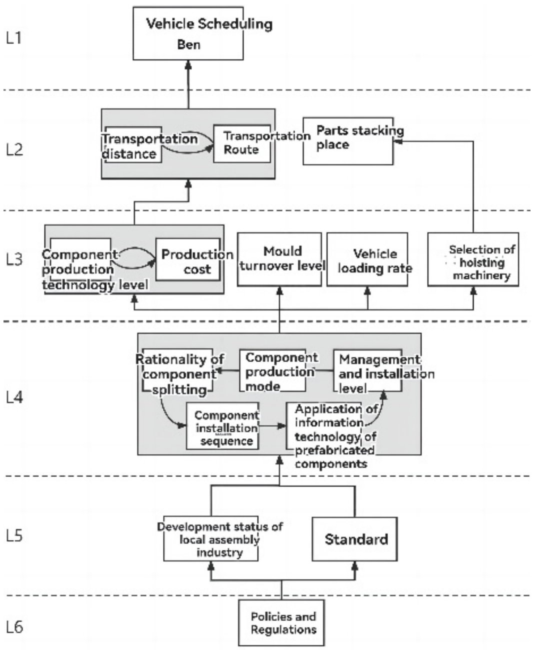

Fig. 2. DOWN hierarchy topology

4 Model Analysis

4.1 Loop Analysis

In the complex matrix model, directed line segments are used to represent the causal relationships between factors. When factors affect each other, these line segments are connected, creating a strong connection between the factors. This strong connection forms a loop among the interconnected factors.

From the figure, it is evident that there are three loops in the factors that influence the cost of assembled components: {component production level, production cost}, {transportation distance, transportation route}, and {component separation rationality, component production mode, management and installation level, component installation order, prefabricated component information technology application}. This indicates a strong correlation between the three groups of factors. Therefore, when controlling the cost of assembled components, these three groups of factors should be considered as a whole. Thus, effectively improving the level of cost management and control.

4.2 Hierarchical Analysis of Influencing Factors

According to the analysis and observation of the UP（Fig.1）and DOWN（Fig.2）hierarchy topology, it can be observed that the influence relationship from the bottom to the top is relatively consistent, and the hierarchical division of each factor is generally similar. According to the existing hierarchical relationship, the system is divided into three levels. At the bottom level, there is factor L6, which includes policies and regulations that form the foundation of the system. In the middle layer, factors L2-L5 contribute to the transition and development of the system. These factors include the local assembly industry development status, norms and standards, component splitting rationality, component production mode, management and installation level, component installation order, the application of prefabricated component information technology, mold turnover level, transportation distance, transportation route, vehicle loading rate, and selection of hoisting machinery. Finally, at the uppermost level, factor L1 includes component production level, production cost, vehicle scheduling cost, and spare parts stacking site, which are closely related to the system. The lower the level factor, the stronger the cause attribute, and the higher the level factor, the stronger the result attribute.

The essential requirement for creating order involves only directed line segments that extend upward and no directed line segments that receive, indicating that this stage only influences and is not influenced by other factors. Research demonstrates that the key factor influencing the cost of assembled components is the order of essence.

The nearest-neighbor algorithm only accepts directed line segments and does not generate any itself. This means that the outcome is solely influenced by other factors and does not reflect the influence of other factors. It is evident that the proximity layer is the primary factor directly affecting the cost of assembled components. If you want to quickly and effectively adjust the cost of assembled components, you can begin by adjusting the proximity to the order factors.

The transition to the order factor involves receiving the directed line segment affected by the lower factor and sending out the directed line segment to the upper factor, thereby affecting the upper factor. In a hierarchical relationship, occupying the middle layer plays a crucial role in connecting the preceding and following levels.

5 Countermeasures and Suggestions

5.1 Increase Policy Support and Accelerate the Development of Assembly Industry

Policies and regulations are the most fundamental factors affecting the cost of prefabricated components. Therefore, it is necessary for the national government level to promote, carry out corresponding research and the implementation of policies and regulations.

5.2 Optimize The Standards and Promote the Industrialization of Production

Due to the diversification of the forms of components, the turnover efficiency of the mold is low. In order to solve these problems, it is necessary to further standardize the implementation of standards for enterprises to improve the standardization and automation of the production of prefabricated components, maintain the high turnover rate of mold utilization, and reduce manual intervention.

5.3 Learn Advanced Technology to Reduce Transportation Costs

In terms of transportation, due to the large self-weight and irregular shape of the components, the vehicle transportation efficiency is low and the components are easy to be damaged by collisions. Enterprises can learn foreign advanced modes of transport, such as "swing transport", which can greatly increase transportation efficiency and avoid component damage caused by bumps and bumps, reducing the cost of using the vehicle.

5.4 All Parties Should Strengthen Cooperation to Build an Assembly-Type Industrial Chain

All enterprises and units related to prefabricated buildings, including government departments, shall strengthen cooperation to build an industrial chain suitable for the development of prefabricated components.

5.5 Strengthen the Application of Information Technology and do a Good Job in the Whole Cycle Linkage of Projects

Promote the application of information technology. In the design stage of assembled components, designers can use BIM software to assist, which is conducive to improving the design quality and optimizing the modeling of components, and avoiding ineffective costs.

6 Conclusions

As one of the most significant challenges in the development of prefabricated buildings, the cost of prefabricated components has been extensively discussed and studied by numerous scholars. Based on previous studies, this paper utilizes the AISM model to investigate the correlation between different factors and enhance the existing theory on the influencing factors of assembled component cost. Compared to traditional ISM analysis, AISM incorporates a reverse extraction hierarchy process. This process enhances the credibility of the comparison between two distinct hierarchy charts, surpassing the effectiveness of traditional single-level charts. Judging from the extracted hierarchy, reducing the cost of prefabricated components requires the collective efforts of enterprises at all stages of the industry. According to the existing problems, this paper proposes suggestions for controlling the cost of assembled components in enterprises. These suggestions cover production, transportation, and the application of information technology, providing a theoretical basis for cost control. But the government agencies still play a leading role in addressing the high cost of assembly components through policies and regulations.

However, due to the limitations of the ISM model, the relationships among factors demonstrated in this paper are still subjective to a certain extent and cannot fully express their objective internal relations. This is an area that can be improved in future research.

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