Research on Supply Chain Risk of Prefabricated Building Based on AHP Model

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Abstract. Under the background of economic development tending to quality development and sustainable development, the traditional building model is difficult to meet the social needs. As a new product of the transformation and development of the construction industry, prefabricated building have entered the public vision. It is particularly important to evaluate and control the risks of prefabricated building supply chain. This paper studies the risks in the supply chain of prefabricated building and builds a risk index system on this basis, uses the analytic hierarchy process (AHP) to achieve risk evaluation, and then proposes risk control measures, which provides some ideas for the risk research of prefabricated building supply chain in China.

Keywords: Prefabricated building · supply chain risk · risk evaluation · AHP

1 Introduction

The construction industry, as one of the pillars of China's national economy, although its total output value has been increasing year by year, its profit margin is relatively low [1], due to the serious waste of materials, high labor costs, and long construction periods in traditional construction models. In addition, traditional construction models also have problems such as high resource consumption, excessive construction waste, and serious environmental pollution. In the new era dominated by quality development and sustainable development, so the prefabricated building model with the characteristics of energy conservation, environmental protection and low construction costs came into being. The prefabricated building mode realizes the whole chain management of integrated architectural design, factory type component manufacturing, prefabricated component installation, integrated space decoration and the informatization management of cash flow, information flow, logistics and business flow in the supply chain [1], which promotes the development of the construction industry and its supply chain node enterprises [9]. The Ministry of Housing and Urban Rural Development also clearly proposed in 2015 that prefabricated building will account for more than 20% of new buildings in 2020 and more than 50% in 2025. As a new building mode, prefabricated building combines all relevant enterprises such as owners, design units, general contractors, subcontractors, and material dealers into a dynamic alliance [2]. Factory production

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and on-site assembly make it have the dual attributes of manufacturing and construction industry [7]. Therefore, prefabricated building supply chain has both industry characteristics, such as many node enterprises, high capital investment, long recovery cycle, etc., so any problem in the supply chain of prefabricated building will affect the whole chain, even the whole industry. Therefore, it is of great significance to identify, evaluate and control the risk of the prefabricated building supply chain. From the perspective of supply chain processes, LI Hongxian and others evaluated the risks of prefabricated building in the construction phase through the fuzzy analytic hierarchy process [3]. From the perspective of the overall supply chain, Sun Changhai divided the risks of the construction supply chain into external environmental risks and internal risks [4].

Based on the characteristics and process of prefabricated building supply chain, this paper analyzes the risk of prefabricated building supply chain and builds a risk evaluation index system, and then uses the analytic hierarchy process to quantify it. Finally, risk control measures are proposed to improve the risk management theory and promote the benign development of prefabricated building.

2 Prefabricated Building Supply Chain Risk and Its Operation Mode

2.1 Prefabricated Building Supply Chain Risk

2.1.1 Gradually Increasing Logistics Costs.

The prefabricated building mode highlights the factory manufacturing, centralized manufacturing and standardized manufacturing of components, and logistics enterprises distribute them to the construction site. Compared with the traditional building mode, the logistics cost has increased. Secondly, in the logistics process, the loss of components, logistics punctuality and other conditions have an impact on the construction period and cost.

2.1.2 Conflict Between Collective Interests and Corporate Interests.

Trading activities closely connect various enterprises to form a supply chain, thereby forming a supply chain network [8]. Compared to the maximization of interests pursued by individual enterprises, the supply chain focuses more on collective interests, enabling all node enterprises in the chain to develop from it. In the increasingly competitive market environment, enterprises with a certain market position inevitably forcibly occupy the deserved interests of other small and medium-sized enterprises in order to obtain more benefits, collective benefit sharing is difficult to achieve. Secondly, node enterprises in the chain use the supply chain as a tool to obtain real data from other enterprises and make business decisions, So supply chain participating enterprises compete to dominate the supply chain in order to grasp the "four streams" of data, resulting in three supply chain operation modes.

2.2 Operation Mode of Prefabricated Building Supply Chain

2.2.1 Core Enterprise Leading Model.

As a node enterprise with a large scale, good financial and credit status, and certain industry and market influence in the supply chain, core enterprises can fully understand the real and effective data of their upstream and downstream through their own trading activities, actively and timely grasp the "four flows" of the supply chain, and have significant advantages in reducing decision-making risks and costs. In addition, Core enterprises can extend their good credit to other node enterprises to obtain financing, which to some extent has achieved a stabilizing effect on the supply chain. However, the funding and aspects of core enterprises still need to be addressed.

2.2.2 Logistics Enterprise Leading Model.

Under the prefabricated building mode, the production place of components is not the same as the installation place of components, so the continuity of installation work requires high timeliness, effectiveness and stability of the logistics network. As an important bridge connecting supply chain nodes, logistics enterprises have strong cargo control capabilities and real-time control of the most direct cargo information. However, they still have limitations in terms of funding.

2.2.3 Commercial Bank Leading Model.

One of the "four flows" of the supply chain is cash flow. As an inevitable feature of the construction industry, large capital investment has become an important factor restricting the development of small and medium-sized node enterprises in the supply chain. Commercial banks are full of funds and have rich experience in risk control. The supply chain financial services launched are deeply embedded in the prefabricated building supply chain, but the limitation is that commercial banks have not participated in the actual trading activities of the supply chain, it is difficult to proactively obtain real data and have limited control over the supply chain.

3 Risk Evaluation Model of Prefabricated Building Supply Chain

3.1 Construction of Prefabricated Building Supply Chain Risk Index System

The premise of reasonable evaluation of supply chain risk is to establish a scientific evaluation index system, so it is necessary to identify the risk of prefabricated building supply chain first. Based on the principle of scientific and independent index screening [6], combined with relevant literature review and the characteristics and processes of prefabricated building supply chain, prefabricated risks are divided into macro risks, production risks, logistics risks, assembly risks and delivery risks. As shown in Fig. 1.

3.2 Analytical Hierarchy Process

Analytic Hierarchy Process (AHP), is a subjective weighting method that decomposes complex elements related to decision-making into a multi-level and multi indicator

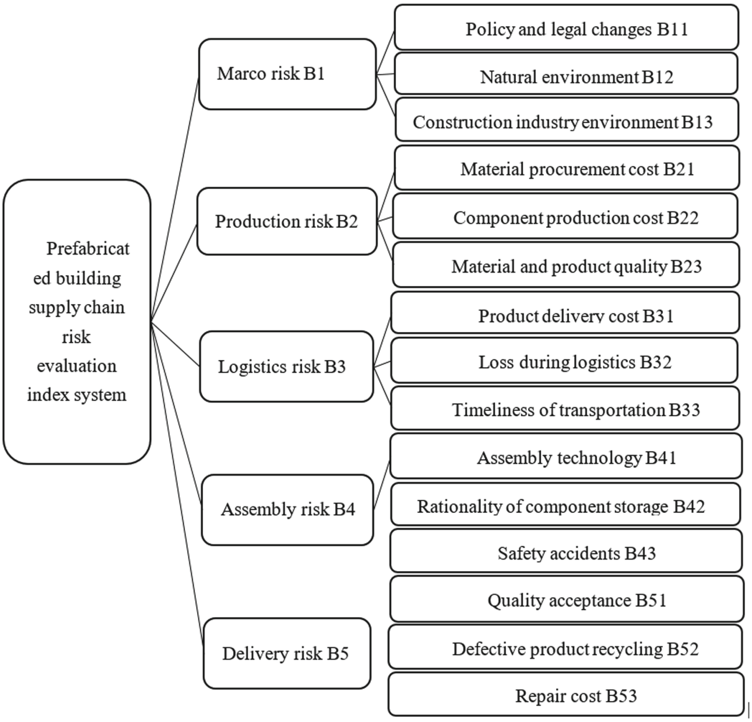

Fig. 1. Prefabricated building Supply Chain Risk Assessment Indicator System

system, and on this basis, achieves a combination of qualitative and quantitative analysis [5]. The calculation steps of the Analytic Hierarchy Process are as follows:
Step 1: Construct a hierarchical judgment matrix

After achieving multi-level classification of research objectives, the relative importance of indicators can be obtained by comparing them in pairs at the same level, and then constructing a judgment matrix A

$$A = \left(a_{ij}\right)_{n \times n} \tag{1}$$

In the formula, it represents the subjective weighting results of each expert based on a scale table of 1–9 for pairwise comparisons at the same level, with the values and their reciprocal in the scale table as the scale, and scale and its meaning are shown in Table 1.
Step 2: Calculate weights

Normalize the elements in A by column to get a new matrix $Z = \left(z_{ij}\right)_{n \times n}$, where z_{ij} is normalized value of a_{ij} column vector, and the formula is;

$$z_{ij} = a_{ij} / \sum_{k=1}^{a} a_{kj} \tag{2}$$

Adding the elements of Z in rows yields is $\alpha = (\alpha_1, \alpha_2, \ldots \alpha_n)^T$, Among them $\alpha_i = \sum_{j=1}^{n} z_{ij}$, normalizing the vector α can obtain the weight vector $W = (w_1, w_2, \ldots w_n)^T$,

Table 1. Scale Tables 1–9

Scale	Meaning
1	Compared to two indicators, they have the same importance
3	Compared to two indicators, one is slightly more important than the other
5	Compared to two indicators, one is significantly more important than the other
7	Compared to two indicators, one is more important than the other
9	Compared to two indicators, one is extremely important compared to the other
2,4,6,8	Compared to two indicators, at the median of two adjacent judgment
Count backwards	$a_{ij} = 1/a_{ji}$

Table 2. Random Consistency Index (RI) Values

order	1	2	3	4	5	6	7
RI	0	0	0.58	0.90	1.12	1.24	1.32

where $w_i = \alpha_i / \sum_{k=1}^{n} \alpha_k$, Find the maximum eigenvalue value as

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^{n} \frac{(AW)_i}{w_i} \tag{3}$$

Step 3: Consistency check

To verify the rationality of obtaining weights, consistency testing is performed on the judgment matrix. CI is a consistency indicator, and R I is the average random consistency indicator, with values shown in Table 2. And the consistency test formula is $CI = \frac{\lambda_{max} - n}{n-1}$, $CR = \frac{CI}{RI}$.

If $CR < 0.1$, the consistency test is passed, otherwise it does not pass. The judgment matrix needs to be reconsidered and reconstructed.

Step 4: Calculate the total weight.

Based on the construction of risk assessment index system for prefabricated building, it is calculated level by level from bottom to top to achieve the weight of the index level relative to the target level.

4 Case Analysis

4.1 Overview of XIong'an Citizen Service Center Project

The Xiong'an Citizen Service Center project is located in the eastern part of Rongcheng, Hebei Province. It is the first project invested and constructed by Xiong'an New Area. The project started construction on December 7, 2017 and was completed and delivered on

March 28, 2018, with a total construction area of 105400 square meters. The assembly rate of this project exceeds 70%. In addition to the steel frame structure, there are a total of 7 buildings in the temporary office area of the enterprise on the north side of the park, covering an area of 33000 square meters. All of them are constructed using modular integrated houses. Standardized products can effectively avoid the uncertainty and randomness of manual operations under traditional building models, while reducing on-site and wet operations, greatly reducing the residual and volatile harmful substances in the rooms, ensure that the internal environment of the building is environmentally friendly and harmless.

4.2 Application of Risk Assessment Model

Distribute questionnaires to experts in the construction field and the project to obtain expert rating results. Based on this, establish a judgment matrix A for the target layer and the criterion layer as follows:

$$A = \begin{bmatrix} 1 & 1 & 3 & 3 & 3 \\ 1 & 1 & 4 & 2 & 2 \\ 1/3 & 1/4 & 1 & 1/3 & 1/2 \\ 1/3 & 1/2 & 3 & 1 & 2 \\ 1/3 & 1/2 & 2 & 1/2 & 1 \end{bmatrix}$$

Simultaneously establish a judgment matrix for each criterion layer on the indicator layer:

$$B_1 = \begin{bmatrix} 1 & 4 & 2 \\ 1/4 & 1 & 1/2 \\ 1/2 & 2 & 1 \end{bmatrix} B_2 = \begin{bmatrix} 1 & 1/2 & 2 \\ 2 & 1 & 4 \\ 1/2 & 1/4 & 1 \end{bmatrix} B_3 = \begin{bmatrix} 1 & 2 & 4 \\ 1/2 & 1 & 2 \\ 1/4 & 1/2 & 1 \end{bmatrix}$$

$$B_4 = \begin{bmatrix} 1 & 1/3 & 1/6 \\ 3 & 1 & 1/2 \\ 6 & 2 & 1 \end{bmatrix} B_5 = \begin{bmatrix} 1 & 2 & 1/3 \\ 1/2 & 1 & 1/4 \\ 3 & 4 & 1 \end{bmatrix}$$

By using the Analytic Hierarchy Process for calculation and analysis, the weights of various indicators of the project can be obtained, as shown in Table 3. According to the consistency check formula, the final CR value calculated is 0.03, which is less than 0.1, so the consistency check is passed.

4.3 Risk Control Measures

From the results, it can be observed that the highest risk weight of policy and law changes is 0.1901. In order to realize the risk control of prefabricated building supply chain, based on the analysis results of Xiong'an Citizen Service Center project, the following risk control strategies are proposed, which is also applicable to other similar projects:

Table 3. Summary of Weights of Project Indicators

Target layer(A)	Criteria layer(B)	Weight	Indicator layer	Relative weight	weight
Prefabricated building supply chain risk evaluation index system	Marco risks B1	0.3328	Policy and legal changes B11	0.5714	0.1901
			Natural environment B12	0.1429	0.0475
			Construction industry environment B13	0.2857	0.0951
	Production risk B2	0.2953	Material procurement cost B21	0.1429	0.0422
			Component production cost B22	0.5714	0.1688
			Material and product quality B23	0.2857	0.0844
	Logistics risk B3	0.0745	Product delivery cost B31	0.5714	0.0426
			Loss during logistics B32	0.2857	0.0213
			Timeliness of transportation B33	0.1429	0.0106
	Assembly risk B4	0.1755	Assembly technology B41	0.3000	0.0526
			Rationality of component storage B42	0.1000	0.0175
			Safety accidents B43	0.6000	0.1053
	Delivery risk B5	0.1219	Quality acceptance B51	0.6232	0.0760
			Defective product recycling B52	0.1373	0.0167
			Repair cost B53	0.2395	0.0292

(1) Pay attention to policy changes and development trends

With the construction industry is undergoing transformation and upgrading, the prefabricated building model has gradually replaced the traditional building model and has flourished. Therefore, prefabricated building should pay attention to changes in national policies, laws and regulations and the development trend of the construction industry, and constantly develop new models of the construction supply chain to establish a stable supply chain network.

(2) Improve the supply chain cost management mechanism

Cost management, as an important part of the supply chain, affects the overall economic benefits of the supply chain. When reworking defective products, we should control reverse logistics and defective recycling to reduce losses. In addition, the characteristics of large volume and complex rework of construction projects require attention to product quality issues in all aspects of the supply chain. Therefore, excessive pursuit of project cost reduction and rough manufacturing are not allowed.

5 Conclusions

Through the research on the characteristics and process of prefabricated building supply chain, combined with the analytic hierarchy process, this paper identifies the risk of the whole process, and concludes that the proportion of policies and laws and regulations in the prefabricated building supply chain, taking Xiong'an Citizen Service Center project as an example, is the highest, and puts forward corresponding risk control measures. At present, most of the research focuses on the static risk research and post risk control of the prefabricated building supply chain as a whole, so the dynamic development and risk warning of the supply chain need to be studied.

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