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Research on Risk Correlation of Prefabricated Residential Building Supply Chain based on DEMATEL-ISM Model

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Abstract: ***In order to solve the problems of prefabricated residential building supply chain, such as more risk factors, high uncertainty and the influence of risk source factors, DEMATEL-ISM method is proposed to analyze the relationship between risk factors. From the outside, management. Manufacturing and transportation, construction and assembly, delivery six aspects of the establishment of risk index system. Combined with the analysis of examples, it is concluded that the total contract management ability and subcontract management ability are the most fundamental influencing factors of the prefabricated residential building supply chain risk, and have a great impact on other factors. Prefabricated installation precision, transfer layer steel bar positioning, delivery timeliness, quality acceptance are the surface factors of prefabricated residential building supply chain risk, and the impact is small. The research results can provide ideas for the correlation of supply chain risk in related projects.***

1. INTRODUCTION

In recent years, China has vigorously promoted the prefabricated building, and the prefabricated residential building model has gradually replaced the traditional residential building, which is more complex than the traditional supply chain model[1]. In response to the national policy, the provinces issued the implementation opinions of prefabricated residential buildings based on the status quo of the province, practicing the concept of green development, replacing traditional residential buildings, and increasing the proportion of prefabricated residential buildings. At present, the prefabricated buildings in most provinces are mainly prefabricated residential buildings, and the development of new building industrialization and intelligent manufacturing is promoted. Compared with traditional residential buildings, prefabricated residential buildings have more participants, longer preparatory work and multiple sources of information[2]. The participants and implementation steps of each "chain" of the supply chain are different from those of the traditional residential building supply chain. The traditional residential building supply chain cannot be fully applied to the prefabricated residential building supply chain. Therefore, it is very necessary to analyze and study the relationship between the risk factors of the prefabricated residential supply chain.

At present, there are relatively many researches on the risk of prefabricated buildings at home and abroad, but there are few researches on the correlation analysis of risk factors. Dinesh Seth et al. [3]analyzed the influence of competition conditions on supplier evaluation through multi-principle decision making, and found out the influencing factors by combining actual construction supply chain cases. Nie J developed a prediction model for the sudden risk of the construction supply chain through data mining and proved the feasibility of the prediction model[4]. Obayi et al. analyzed the cost risk management strategy in the construction supply chain by case study and obtained the core driving factors of risk[5]. Considering that prefabricated buildings have more uncertain risks, Zhu Tian et al. combined WBS-RBS and BP neural network to provide a new risk prediction model[6]. Wang Xiang et al. used the combination of EFA and CFA to get the factors affecting the coordinated development of prefabricated building supply chain and reveal the key points of risk control[7]. Wang Jianghua et al. introduced the idea of interface management, used C-OWA operator and grey cluster evaluation method to build an evaluation model and find out the key points of risk control[8]. To sum up, the above domestic and foreign literatures have used different methods or models for reference to the supply chain risk of prefabricated residential buildings, but they rarely conduct excessive analysis on the correlation of risk factors of prefabricated residential buildings, and fail to clarify the influence of various factors among risks. Therefore, by means of literature research, questionnaire survey and expert interview, combined with the actual case of Henan Province, this paper uses FAHP-DEMATEL-ISM model to determine the correlation among prefabricated residential building risk factors, identify surface, middle and deep risk factors, and determine the hierarchical relationship among risks[9].

In view of this, this paper proposes the DEMATEL-ISM model, divides the levels of risk factors into clear displays, analyzes the levels of risk, and uses actual cases for empirical research to analyze the risk correlation, which provides ideas for the risk correlation analysis of the prefabricated residential building supply chain and is conducive to subsequent risk management.1 Construction of prefabricated residential building supply chain risk influencing factor system.

2. CONSTRUCTION OF PREFABRICATED RESIDENTIAL BUILDING SUPPLY CHAIN RISK INFLUENCING FACTOR SYSTEM

Based on 80 academic journal papers on prefabricated building supply chain, 51 academic journal papers on prefabricated building supply chain, 24 academic journal papers on prefabricated building supply chain risk, and 92 academic journal papers on construction supply chain risk, this paper preliminarily sorted out relevant risk sources, excluded irrelevant papers, and searched for related prefabricated building policies issued by Henan provincial government. After interviews with experts engaged in prefabricated residential construction industry, college teachers and other experts engaged in related research, the risk sources with less impact are eliminated, and six risk criteria are preliminarily determined, namely external risk, management risk, procurement risk, manufacturing and transportation risk, construction and assembly risk, and delivery risk, and 25 risk risk sources are sorted out, as shown in Table 1.

Table 1: Risk index system of prefabricated residential buildings

Target layer	Criterion layer	Indicator layer
	Primary index	Secondary index
Prefabricated residential building supply chain risk index system	External risk B1	Risk of policy economic change B11
		Social risk B12
		Natural environmental risk B13
	Management risk B2	Total package management capability B21
		Construction organization design integrity B22
		Procurement Management B23
		Schedule Management B24
		Subcontract management capability B25
		Deepen design B26
		Reasonableness of contract content B27
	Procurement risk B3	Quality level of purchased materials B31
		Procurement information source accuracy B32
		Procurement cost B33
	Manufacturing and transportation risks B4	The fabrication time of prefabricated components is reasonable B41
		Prefabricated components strength, size design specification rationality B42
		Transport timeliness B43
		Transport process component integrity B44
	Construction and assembly risk B5	Site construction environment B51
		Tower crane position and anchoringB52
		Prefabricated installation accuracy B53
		Transfer layer rebar positioning B54
		Timely detection of hazard sources around the construction site B55
		Personnel technical capabilityB56
	Delivery risk B6	Delivery timeliness B61
		Quality acceptance B62

3. CONSTRUCTION BASED ON DEMATEL-ISM MODEL

3.1 Introduction to DEMATEL-ISM Model

DEMATEL (Decision Laboratory method) considers the influence relationship between the two factors and the brief influence relationship [10]. ISM (Interpretive structural model method) is a structural modeling technology that can stratify each influence factor[11]. The combination of the two can minimize the calculation amount and integrate the advantages of the two. The DEMATEL method is used to calculate the impact degree, and the ISM method is combined to stratify the impact degree, and then the importance of the secondary risk indicators and the logical relationship between the factors are analyzed, which adds a new perspective and content for the subsequent prefabricated residential building risk assessment. The flowchart of the combination of the two is shown in Figure 1.

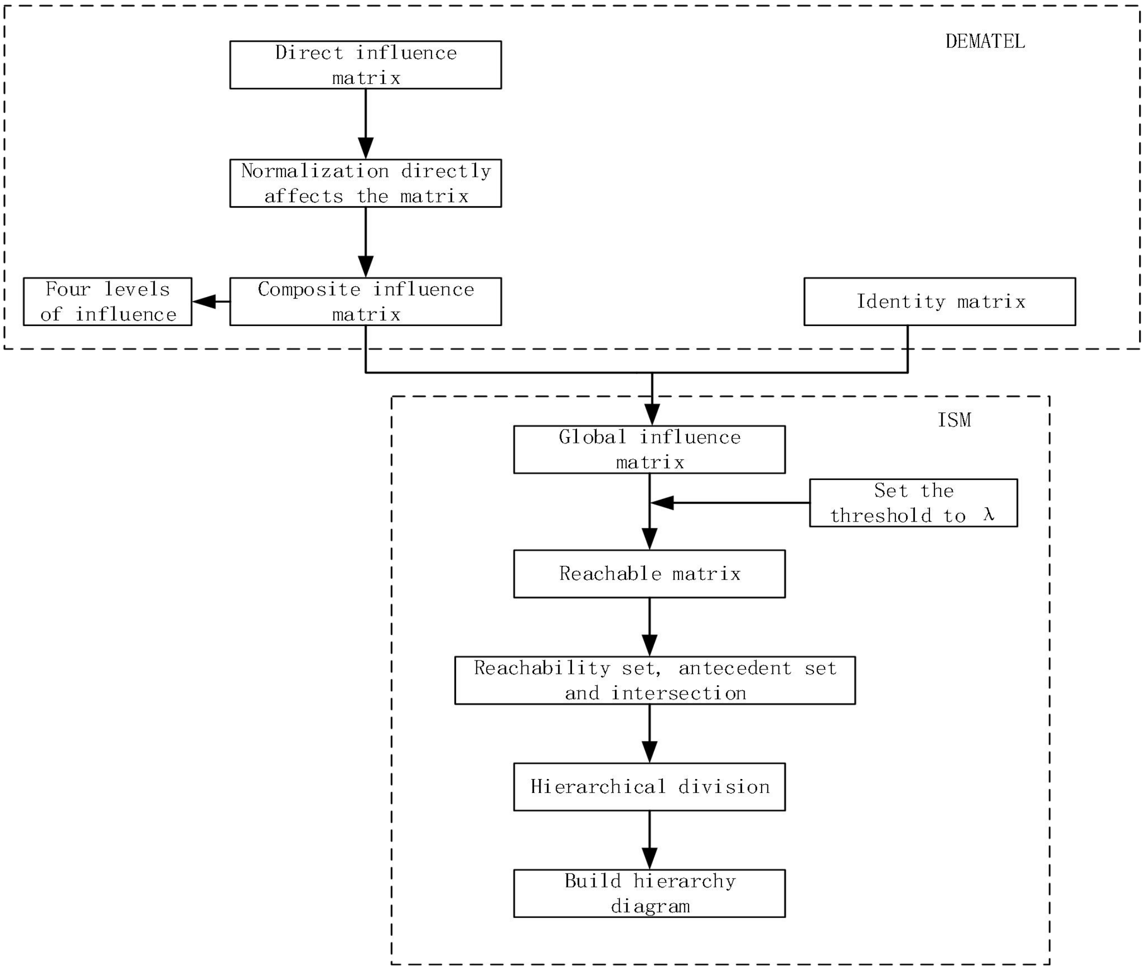

Figure 1: DEMATEL-ISM flowchart

3.2 DEMATEL Calculates the initial weights

DEMATEL method is to calculate the influence degree of each factor on other factors and the degree of influence through the logical relationship and direct influence matrix among the factors in the system, so as to calculate the cause degree and centrality of each factor, and determine the causal relationship between the factors and the status of each factor in the system.

(1) Establish an evaluation index system. The index system is determined by the expert interview method and Delphi method, and after collecting information, each element in the system is recorded as G1,G2,G3, etc. ... Gm.

(2) Construct the direct influence matrix. The relationship among indicators is analyzed, and the influence degree among indicators is expressed according to the 0-3 scale method, in which 0= no influence, 1= influence, 2= great influence, 3= strong influence, direct influence matrix. The influence degree of indicator Gi on indicator Gj at the same level is expressed by Gij, and the influence degree of indicator Gi on itself is Gij=0.

Normalization of the direct influence matrix. The direct influence matrix G is normalized and matrix B is obtained.

$$G_i = \max\{\sum_{j=1}^{n} G_{ij}\} \tag{1}$$

$$b_{ij} = \frac{G_{ij}}{G_i} \tag{2}$$

$$B = (b_{ij}) \tag{3}$$

(4) Calculate the comprehensive influence matrix. According to matrix B, the comprehensive influence matrix T is obtained.

(5) Calculate the impact level and the affected level. Impact fi is the sum of all elements of the comprehensive impact matrix T, and impact hi is the sum of all columns of the comprehensive impact matrix T. The formula for calculating impact and impact is as follows.

$$f_i = \sum_{j=1}^{n} t_{ij} \tag{4}$$

$$h_i = \sum_{i=1}^{n} t_{ij} \tag{5}$$

(6)Calculate the degree of centrality and reason. The centrality degree is denoted as mi, and the cause degree is denoted as ri. The larger the centrality degree is, the more important the indicator is. If the cause degree is greater than 0, it indicates that the indicator is easily affected by other factors, which is called the result factor; on the contrary, if the cause degree is less than 0, the indicator is easily affected by other indicators, which is called the cause factor.

$$m_i = f_i + h_i \tag{6}$$

$$r_i = f_i - h_i \tag{7}$$

3.3 DEMATEL-ISM risk factor analysis

The combination of DEMATEL and ISM is helpful to clarify the internal relationship between the system's influencing factors, intuitively display the fuzzy relationship between the system's influencing factors, identify the degree of their influence, and quantitatively describe the degree of influence among the influencing factors. The calculation steps are as follows:

(1) The overall influence matrix is obtained by adding the comprehensive influence matrix and the identity matrix calculated by DEMATEL in Chapter 2.1.

$$O = T + I = (o_{ij})_{n\times n} \tag{8}$$

The standard reachable matrix is obtained. The reachable matrix is to set a reasonable threshold value, the function of which is to eliminate the factors with less influence. The value of the reachable matrix can be determined by combining the expert opinions and the actual situation through Equation 8 to transform the overall influence matrix into an reachable matrix.

$$K_{ij} = \begin{cases} 1 & o_{ij} \geq \lambda(i,j = 1,2,\ldots,n) \\ 0 & o_{ij} < \lambda(i,j = 1,2,\ldots,n) \end{cases} \tag{9}$$

Importance analysis among risk factors. The factor analysis diagram can be obtained by analyzing DEMATEL.

(2) Draw hierarchical plots. The model is decomposed according to the reachable matrix hierarchy. In each extraction, if the intersection between reachable set and reachable set and prior set is found to be consistent, the element set can be extracted for hierarchical division, and the results of reachable set, prior set and intersection can be obtained.

(3) Hierarchical correlation analysis of risk factors. The hierarchical correlation analysis of risk factors was obtained according to the hierarchical diagram, and the surface, middle and deep factors were obtained.

4. CASE ANALYSIS

4.1 Project Overview

A prefabricated residential building project is located in Zhengzhou, Henan Province, with a total assembly area of 70,000 square meters, of which stairs, laminated panels, air conditioning panels, wall panels, bay Windows and other five categories are prefabricated components, and the overall prefabrication rate is about 50%.

4.2 Determine the model parameters

The model questionnaire was filled out by 8 experts from different units who have worked in prefabricated residential buildings for more than 15 years, including 2 university professors who have professional theoretical knowledge and have been engaged in the evaluation of prefabricated residential buildings for a long time, and 6 engineers and managers who have rich experience in the field. All the experts have accumulated long-term knowledge on the subject of the study. On the basis of the project, the experts use the existing professional knowledge to score each risk factor and obtain the initial scoring table. The calculation process is shown in sections 3.1 to 3.3.

4.3 Calculation by DEMATEL method

The "fourth degree" of DEMATEL is calculated according to equations (1) ~ (7), See Table 2.

Table 2: DEMATEL's "Four Degrees"

Factor	Influence degree	Influence degree	centrality	Causation degree	Sort
B11	0.516	0.220	0.736	0.296	15
B12	0.338	0.330	0.667	0.008	16
B13	0.544	0.300	0.844	0.244	13
B21	0.955	0.059	1.014	0.896	11
B22	0.208	0.186	0.394	0.022	23
B23	0.713	0.332	1.045	0.380	9
B24	0.359	0.954	1.313	-0.596	6
B25	0.450	0.059	0.509	0.391	20
B26	1.299	0.066	1.365	1.232	4
B27	0.162	0.068	0.230	0.095	25
B31	0.562	0.879	1.441	-0.316	3
B32	0.499	0.290	0.789	0.209	14
B33	0.356	0.672	1.028	-0.317	10
B41	0.431	0.131	0.561	0.300	19
B42	0.289	0.192	0.482	0.097	21
B43	0.151	0.289	0.440	-0.138	22
B44	0.141	0.151	0.292	-0.010	24
B51	0.686	0.385	1.071	0.300	8
B52	0.319	0.647	0.966	-0.328	12
B53	0.349	0.965	1.314	-0.617	5
B54	0.075	0.489	0.564	-0.414	18
B55	0.617	0.465	1.083	0.152	7
B56	0.593	0.059	0.652	0.533	17
B61	0.132	1.458	1.590	-1.325	1
B62	0.189	1.285	1.474	-1.096	2

According to the centrality and influence degree calculated by DEMATEL method, the mutual influence relationship diagram and cause-result diagram of prefabricated residential building supply chain risk under the general contracting mode are made, as shown in Figure 1. The factors in areas I and IV are the cause factors, and the factors in areas II and III are the result factors.

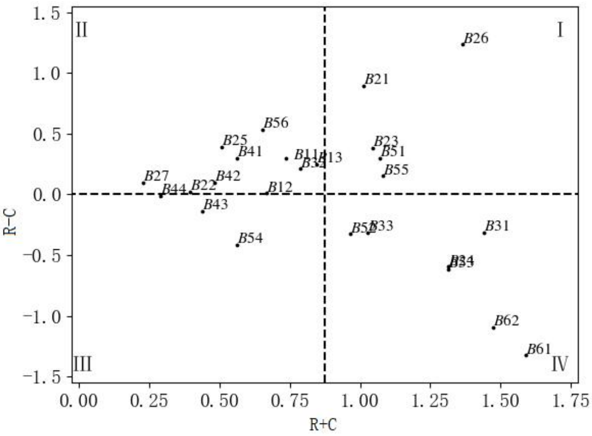

Figure 2: Cause-effect diagram

4.4 DEMATEL-ISM calculates risk association

The 25 risk indicators of prefabricated residential building supply chain risk determined, the DEMATEL results calculated in Section 3.2, and the ISM model were combined to divide the levels and determine the risk correlation. The standard reachability matrix is determined by equation (8) and (9), and the initial reachability set, antecedent set and intersection are obtained according to the standard reachability matrix. The factors are classified through 6 times decomposition until the reachability set, antecedent set and intersection are completely decomposed. The results are shown in Table 3.

Table 3: Reachability set, antecedent set, intersection, and level

Factor	Reachable set	Precedence set	Intersection	Rank
B11	[1,2,3,5,10,11,12,13,25]	[1,2,3]	[1,2,3]	L5
B12	[1,2,3,12]	[1,2,3,4,8]	[1,2,3]	L4
B13	[1,2,3,7,16,18,22]	[1,2,3,18,22]	[1,2,3,18,22]	L4
B21	[2,4,7,8,19,20,22,24,25]	[4,8]	[4,8]	L6
B22	[5,19,20,21]	[1,5,9]	[5]	L5
B23	[6,11,12,13,15,17,24,25]	[6,7,9,12,13]	[6,12,13]	L2
B24	[6,7,20,24,25]	[3,4,7,8,9,10,11,14,16,18,19,22,23]	[7]	L3
B25	[2,4,7,8,24,25]	[4,8]	[4,8]	L6
B26	[5,6,7,9,11,14,15,19,20,21,23,24,25]	[9,15]	[9,15]	L3
B27	[7,10,11]	[1,10]	[10]	L4
B31	[7,11,13,24,25]	[1,6,9,10,11,12,13,15,20]	[11,13]	L2
B32	[6,11,12,13,14,24,25]	[1,2,6,12]	[6,12]	L4
B33	[6,11,13,25]	[1,6,11,12,13]	[6,11,13]	L2
B41	[7,14,16,22,24,25]	[9,12,14]	[14]	L5
B42	[9,11,15,20,25]	[6,9,15]	[9,15]	L3
B43	[7,16,24]	[3,14,16,22]	[16]	L4
B44	[17,20,25]	[6,17,18]	[17]	L2
B51	[3,7,17,18,19,20,21,22,24,25]	[3,18,19,22,23]	[3,18,19,22]	L4
B52	[7,18,19,20,24]	[4,5,9,18,19,20,22,23]	[18,19,20]	L3
B53	[11,19,20,21,24,25]	[4,5,7,9,15,17,18,19,20,21,22,23]	[19,20,21]	L1
B54	[20,21]	[5,9,18,20,21,23]	[20,21]	L1
B55	[3,7,16,18,19,20,22,24,25]	[3,4,14,18,22,23]	[3,18,22]	L4
B56	[7,18,19,20,21,22,23,24,25]	[9,23]	[23]	L5
B61	[24,25]	[4,6,7,8,9,11,12,14,16,18,19,20,22,23,24,25]	[24,25]	L1
B62	[24,25]	[1,4,6,7,8,9,11,12,13,14,15,17,18,20,22,23,24,25]	[24,25]	L1

As can be seen from the figure above, the risk of prefabricated residential building supply chain is divided into six levels according to the element level decomposition table, and a hierarchical structure chart is drawn to clearly list the correlation of various factors as well as the deep, middle and surface factors, as shown in Figure 3 below.

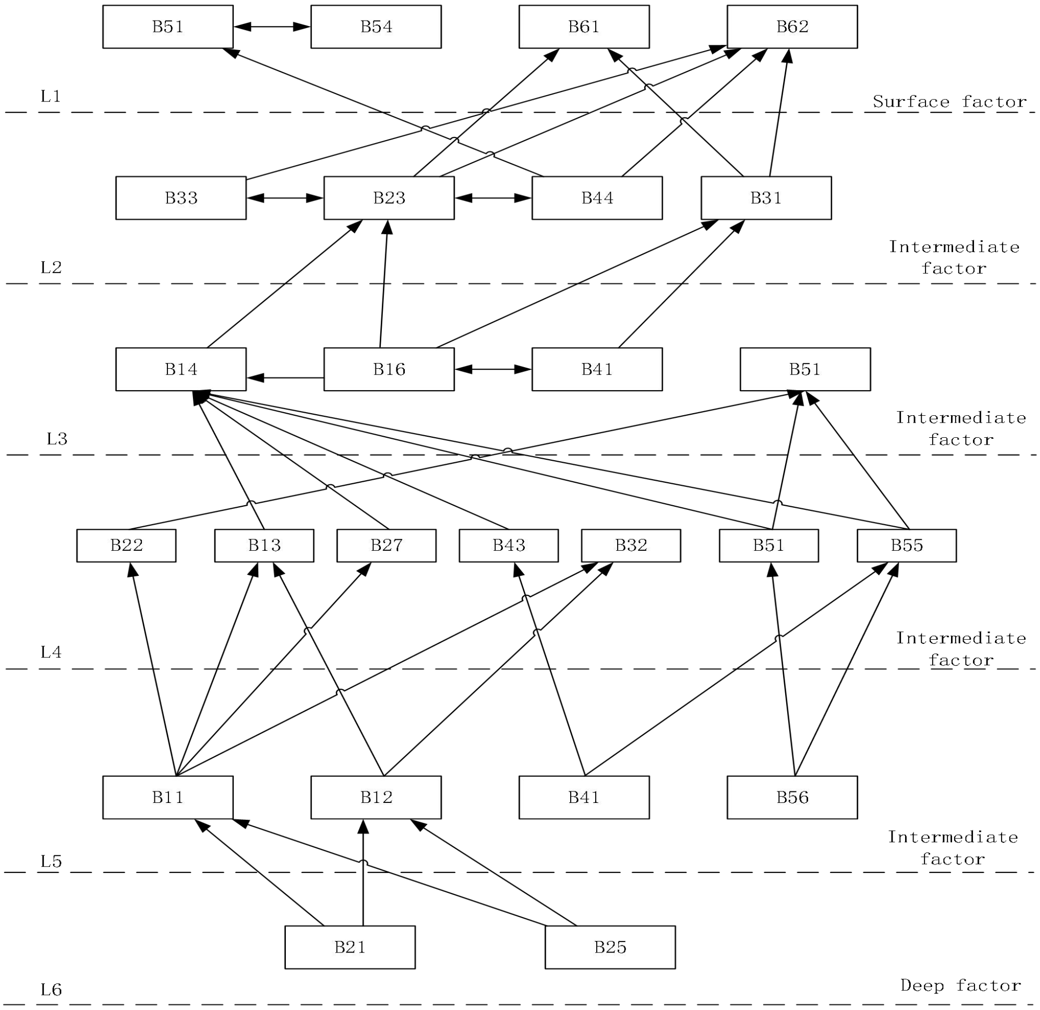

Figure 3: Hierarchical structure diagram

It can be clearly seen from the figure above that the total contract management level ability B21 and subcontract management ability B25 are deep factors, which have a greater impact on other factors, while the prefabricated installation accuracy B51, the transfer layer rebar positioning B54, the delivery timeliness B61 and the quality acceptance qualification B62 are surface factors, which have a small impact on the whole. Therefore, the total contract management ability and subcontract management ability have a greater impact on the internal risk factors of the prefabricated residential building supply chain, and should be paid priority attention to.

5. CONCLUSION

(1) This paper carries out risk analysis based on the characteristics of the prefabricated residential building supply chain, finds out the correlation between the risks, takes into account the risks in the six stages of the prefabricated residential building supply chain, management, procurement, manufacturing and transportation, construction and assembly, and delivery, identifies and collates 25 risk factors based on the six first-level index risks by combining examples. It provides the basis for the follow-up study of risk correlation.

(2) Prefabricated residential building supply chain risk factors affect each other, choose DEMATEL-ISM to study the risk correlation of prefabricated residential building supply chain, analyze the risk factor correlation, draw hierarchical structure chart, clearly represent the levels and important levels of each factor, which is conducive to targeted risk management.

(3) This model provides a new idea for the correlation analysis of risk factors in similar projects, which is convenient for the management of subsequent projects. In the future model, this model and dynamic risk monitoring should be taken into account to realize real-time monitoring of risks and help reduce the occurrence of risks [11].

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