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Analysis of key risk factors for prefabricated building projects based on social network analysis

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Abstract. With the continuous development of prefabricated buildings, their quality issues are getting more and more attention. With a view to improving the risk management of the qualitative aspects of prefabricated buildings, determine the whole process quality risk indicators for prefabricated buildings from the whole life cycle. Risk factors are identified through literature research and questionnaire survey method, and the whole process quality risk assessment model of prefabricated building is constructed based on social network analysis. Combined with the specific quality risk indicators network role analysis to determine the key risks, the study found that the design and construction stages are where key risk factors are most likely to be present, respectively, the design of the actual constructability is poor, the design of the integration is insufficient, the field workers are inexperienced in construction, the actual feasibility of the construction is poor, the construction equipment is not advanced enough. Targeted coping strategies are proposed according to the key risks.

Keywords: social network analysis, prefabricated buildings, stakeholder, risk network

1. Introduction

Compared with traditional cast-in-place buildings, prefabricated buildings have obvious advantages in terms of energy conservation and environmental protection, improved work efficiency and shortened construction period, and are seen as a solution to the growing demand for construction [1]. With the structural adjustment and upgrading of China’s construction system and technological innovation, prefabricated buildings have gained strong national support and promotion. This means that the implementation of prefabricated buildings will face greater challenges and risks. In this context, analyzing the risk factors of prefabricated buildings has become an effective way to guarantee project quality and improve construction efficiency. However, due to the large number of links and participants involved, problems may come from many aspects, and prefabricated building projects face great risks in the whole process. Therefore, it is especially important to analyze the risk factors for prefabricated building projects.

The risk factors that may arise in the whole process of the prefabricated building project are not single and independent, but interact with each other, are closely related, and have uncertainty. Based on the current situation, the study of risk factors in prefabricated building projects is mainly limited to the construction stage, and lacks consideration of compound risk factors and the impact between risks. Due to the complex relationship between the risk factors of prefabricated buildings, the study of individual risk factors does not reflect the characteristics of the prefabricated building industry [2]. Hu Longwei et al. constructed a network model of quality influencing factors of prefabricated buildings through the literature frequency statistics method and expert interviews; Huang Guilin et al. identified risk factors in the green supply chain of prefabricated buildings in terms of stakeholders and established an SNA model for risk assessment; Chai Visits used gray correlation analysis to recognize risk factors from a two-dimensional view across the entire life cycle as well as from the stakeholders, and then summarized the risk factors at three levels of analysis, namely, macro, meso, and micro, and then summarized the risk factors at three levels of analysis, including macro, meso, and micro, micro level analysis to summarize the risk; Zhan Chen defined the influence between risk factors as conditional probability, and conducted risk assessment of each risk factor through the defined model and calculation formula.

Social network analysis method is a bridge between qualitative and quantitative, which quantitatively analyzes a large amount of graphical data to draw qualitative conclusions. Introducing the social network analysis method in the risk factor profiling of prefabricated buildings can analyze the whole process of prefabricated building projects more effectively. Based on this, in order to reduce the risk indicators in the prefabricated building project and improve the quality of the prefabricated building, this paper is in accordance with the social network analysis method, for finding out the mutual influence relationship between the factors affecting the prefabricated building project and constructing the risk network visualization model. In addition, by screening the core risk factors and proposing countermeasures, it can help to solve some of the problems in prefabricated building projects provide a theoretical basis for the assessment of risk factors in prefabricated building projects [3].

2. Literature review

2.1. Factors for analyzing the quality

Prefabricated Building is the prefabrication of components in advance in the factory, and then connected to install at the construction site. It is an innovation in construction technology and methods in contrast to traditional cast-in-place construction. The traditional method, which means a large number of workers are required to construct the site, relies heavily on on-site manual labor, and is characterized by problems such as poor quality control, low production efficiency, and serious material waste. Prefabricated buildings can improve efficiency and reduce costs as well as meeting the requirements of green building, energy saving and environmental protection. In addition, prefabricated building can realize the integration of construction and decoration, which can make the decoration synchronized with the main construction of the project [4]. It is due to these advantages that prefabricated buildings have been strongly supported and promoted worldwide in recent times. Whether it is to adapt to the basic concept of sustainable development in the world, or to adapt to the trend of modern intelligent production, prefabricated building is very significant. Prefabricated building is also an inevitable product of the times. Due to the novel construction technology, long construction period, and large number of participating units in prefabricated building projects, there may be huge risks in the process of project implementation. Project risk management includes several parts of risk identification, which includes risk identification, risk analysis, risk assessment, and risk response. This paper focuses on the analysis of risk factors of prefabricated building, that is, based on the risk assessment model obtained from risk identification to carry out targeted analysis and find the universal law. Based on this, risk avoidance methods can be proposed to improve the quality of the project.

2.2. Social network analysis

The method of social network analysis, also known as structural analysis method, is mainly used to analyze the relational structure of social networks and their properties. The implication of social network analysis is that it can provide a quantitative tool for the structuring of certain mid-level theories and the testing of empirical propositions through the precise quantitative analysis of relationships. It is even possible to build a bridge between the “macro and the micro” [5]. The advantage of using social network analysis is that the research literature is the essence of the research results of experts, representing the consensus of experts and peers, which is authoritative and reliable. Moreover, the sample is obtained in such a way that the comprehensiveness and completeness of the sample can be guaranteed if it is based on the existing research literature. Using a large amount of literature for research can also reflect the characteristics of big data. In addition, social network analysis methods are seen as an improvement of statistic methods, which not only can make statistical inference on large samples, but also can add relational factors, which ensures the accuracy and precision of the extracted indicators [6].

The English anthropologist Radcliffe Brown used the term "network of social relations" in 1940 to describe social structure. German sociologist and philosopher Simmel Georg (1955) studied the behavior of individuals in groups and concluded that different networks influence human behavior. The first scholar to apply the concept of "social network" was Barnes (1954) of the University of Manchester, who studied an informal social network based on friendship, kinship and neighborly relations. This was a direct contribution to the initial formation of the idea of social network analysis. The social network analysis method is maturing as a new technique, and the field of application is expanding. In 2010, Shen Qiping deeply analyzed the strengths and weaknesses of three famous stakeholder management models. Accordingly, the research objective of establishing a systematic management model based on the theory of social network analysis was proposed, and social network analysis was introduced into the field of construction project management. In recent years, with the popularity of assembled buildings, there are also many literatures mentioning the combination of SNA with risk management of assembled buildings. Yi Hongyu utilizes the social network analysis method to analyze the schedule risk network of assembled residential projects as a whole and individually. Through the questionnaire method, key risks and key relationships are identified and targeted strategies are proposed. Based on the relationship perspective, Wang Roujia identifies risk relationships through SNA, considers internal factors that occur within the project and are closely related to project stakeholders, and finds angles to manage risks at the source. Thus, applying the social network analysis method to the risk management of assembled buildings obviously helps us to identify the key risks and analyze to come up with targeted countermeasures.

2.3. Main metrics in SNA

Network density is the proportion of the number of edges actually existing in the network to the maximum number of edges that can be accommodated [7]. The expression formula is shown in equation (1). Where Density(G) represents the network density of a directed network G, K represents the number of relationships that actually exist, N represents the total number of nodes in the directed relationship network G, and RSM represents the factor structure matrix constituted by the influence between any pair of factors Ri-Rj. The network density can indicate the degree of connectivity between nodes that are already connected, and is an important indicator of how tight the network is.

$$Density(G) = \frac{K}{N(N-1)} = \frac{\sum_{Ri,Rj \in G} RSM_{Ri,Rj}}{N(N-1)} \quad (1)$$

The degree centrality is the number of points in the network that are in direct connection to that point. The importance of a node in a network depends mainly on the position of the node in the network, which is the node's node degree, the more central the position of the node is the more important it is, and the number of points directly connected to the point is also more. In directed networks, node degree is categorized into out-degree and in-degree. Out-degree denotes the number of edges pointing from nodes to other nodes, reflecting the degree of influence of the risk on other risks, as shown in equation (2). The in-degree indicates the number of edges pointing to the node from other nodes, reflecting the degree of influence of the risk on other risks, as shown in equation (3). The higher the in-degree, the wider the spread of the node's first information. The higher the out-degree, the faster the node obtains the first information of other nodes. The gap-degree is the difference between the degree and the in-degree. The expression formula is shown in equation (4).

$$OutDegree_{Ri} = \sum_{Ri \in G} RSM_{Ri,Rj} \quad (2)$$

$$InDegree_{Ri} = \sum_{Ri \in G} RSM_{Ri,Rj} \quad (3)$$

$$GapDegree_{Ri} = OutDegree_{Ri} - InDegree_{Ri} \quad (4)$$

The ability of a risk factor to control the transmission of risk in a network can be measured using the betweenness centrality of a point. The intermediate centrality of any point i in the network is calculated in equation (5). where bij(i) is equal to the probability that i is on the shortcut between point j and point k.

$$C_i = \sum_j^n \sum_k^n b_{jk}(i)\,, j \neq k \neq i, j < k \quad (5)$$

3. Methodology

3.1. Development of a risk list

By combing through a large amount of literature and researching projects that have been well implemented, 12 risk factors are summarized from four life cycle phases, namely, design phase, production phase, construction phase, and operation and maintenance phase, and the complete risk list is shown in Table 1, which is coded by using S*R#, where S1 indicates the design unit, S2 indicates the production unit, S3 indicates the transportation unit, S4 indicates the construction unit, and S5 indicates the property unit. construction unit, and S5 indicates the property unit.R1, R2, R3, and R4 are the serial numbers of risk factors under different life cycle stages, respectively.

Table 1. Risk list of factors influencing the quality of prefabricated buildings

Life-cycle stage	Stakeholder	Risk	Risk description
Design	Designer	S1R1	Poor design for practical constructability
		S1R2	Insufficient design integration
		S1R3	Insufficient experience of designers
Manufacturing and transportation	Manufacturer	S2R1	Unstandardized production processes for components
	transporter	S3R1	Inadequate component transportation system
		S3R2	Untimely supply of components
Construction	Contractor	S4R1	Insufficient construction experience of on-site workers
		S4R2	Poor physical feasibility of construction
		S4R3	The construction unit was not completed on time
		S4R4	Insufficiently advanced construction equipment
Maintenance	Facility manager	S5R1	Untimely operations and maintenance
		S5R2	Lack of maintenance experience of relevant personnel

3.2. Constructing the adjacency matrix

The factors affecting the quality of assembled buildings shown in Table 3.1 were recorded as R1-R12 in order, and a questionnaire was made and distributed to the teachers and students of civil engineering. According to the results of the questionnaire, with the number of survey results exceeding 50% as a benchmark, those who believe that the factors in the columns have an influence on the factors in the rows are labeled as “1”. If it is considered that the two factors have no influence, it is labeled as “0”. Finally, the adjacency matrix of factors influencing the quality of assembled buildings is formed, as shown in Table 2.

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Table 2. Adjacency matrix of factors influencing the quality of prefabricated buildings

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12
R1	0	0	1	1	1	1	1	1	0	1	0	0
R2	1	0	0	0	0	0	0	0	0	1	0	0
R3	0	0	0	1	0	0	0	0	0	1	0	0
R4	0	0	1	0	0	0	0	0	0	0	0	0
R5	0	0	0	0	0	0	0	0	0	0	0	0
R6	1	1	1	1	1	0	0	0	0	0	0	0
R7	0	0	0	0	0	0	0	1	1	1	0	0
R8	1	1	1	1	1	1	1	0	0	1	0	0
R9	1	0	1	1	1	1	1	1	0	1	0	0
R10	0	0	0	0	0	0	1	0	0	0	0	0
R11	0	1	0	0	0	0	0	0	0	0	0	1
R12	0	0	0	0	0	0	0	0	0	0	1	0

3.3. Building social networks Building social networks

Social network analysis is an effective way to understand and analyze the network structure as a whole, so it is necessary to construct a reasonable and correct risk network in order to help us analyze the relationship between risk factors. In this paper, we construct the risk network based on the final identified prefabricated building risk list table 3.2, and utilize ucinet6 software to analyze it in depth, so as to observe the influence between risk factors.

4. Results and analysis

4.1. Social network visualization

Risk network data visualization is achieved through ucinet6 software, and the risk factor network visualization model can be obtained as shown in Figure 1. It can be observed in the model that R11 and R12 are relatively independent of other risk factors, which may be related to the fact that the sample of research cases is too small and the study of risk factors is not comprehensive.

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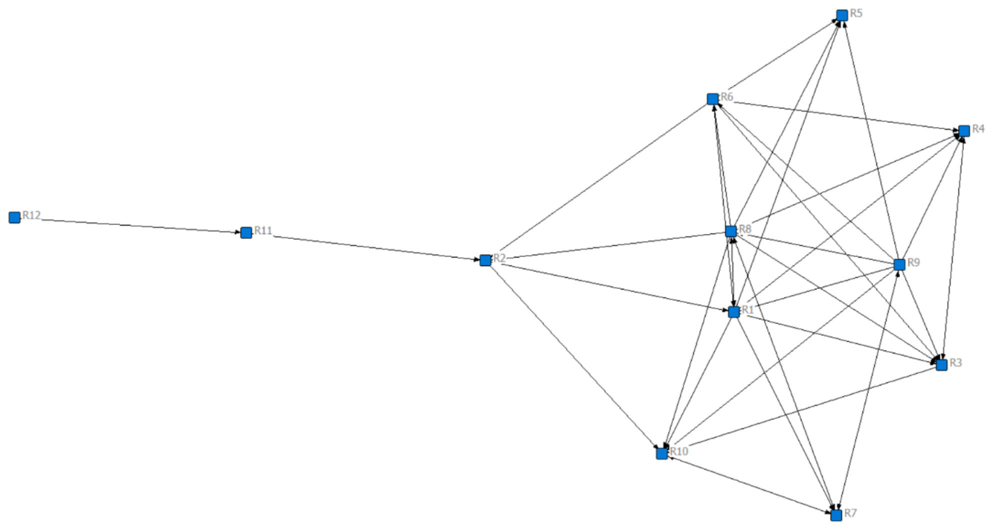

Figure 1. Risk Network Visualization Model

4.2. Analysis of relevant factors

The tightness of the overall net is controlled by the density. The results of density calculation according to ucinet6 are shown in Table 3.

Table 3. The density of the network

Density
0.3030

The selection of indicators with higher betweenness centrality is aimed at screening risk indicators that have a stronger role in controlling risk transfer. The results of calculating the betweenness centrality according to ucinet6 are as shown in Table 4.

Risk indicators with higher degree centrality and higher risk values are selected with the aim of filtering out risk indicators with high local impact. According to ucinet6 point degree centrality calculation results are shown in Table 5.

Table 4. The density of the network

Risk	Betweenness
R1	21.333
R2	18.333
R3	8.333
R4	0
R5	0
R6	1
R7	26
R8	8
R9	8
R10	17
R11	10
R12	0

Table 5. The outdegree and indegree of the network

Risk	Outdegree	Indegree
R1	7.000	4.000
R2	2.000	3.000
R3	2.000	5.000
R4	1.000	5.000
R5	0.000	4.000
R6	5.000	3.000
R7	3.000	4.000
R8	8.000	3.000
R9	8.000	1.000
R10	17.000	6.000
R11	10.000	1.000
R12	0.000	1.000

Based on the data calculated by ucinet6, the top 4 in order of betweenness centrality, from largest to smallest, are S4R1, S1R1, S1R2, and S4R4. the risk indicators are ranked according to the size of the difference in degree as a supplement to the key risk factors that may have been omitted from the intermediate centrality. The top 4 were filtered as S4R3, S4R2, S1R1, and S2R3. S3R2 was supplemented as a key risk considering its large risk value. As a result, the key risk factors present in assembled buildings can be identified as S1R1, S1R2, S4R1, S4R2, and S4R4.

5. Discussion

From the whole process network analysis, the key factors mainly lie in the design stage and construction stage, the corresponding stakeholders are the designer and developer, which need to be focused on in the actual project. The corresponding countermeasure strategies are proposed for the above risks, as shown in Table 6.

Table 6. Strategies to the key risk factors

Risk	Life stage	Strategy
S1R1	Design	Discussions with production and construction units and other parties to reduce the impact of asymmetric project information; use of intelligent technology, including BIM, to pre-simulate the entire design program and adjust the program in a timely manner.
S1R2	Design	Project design should make more use of intelligent technology, in-depth consideration from various aspects, so as to increase the design functions, and ultimately enhance the integration of the design.
S4R1	Construction	Strengthen the training of site personnel, enhance the personnel management of the construction unit, and carry out a more reasonable staff regulation.
S4R2	Construction	Communicate with designers and owners to fully understand project requirements; rationalize the construction process to ensure that the construction is not overly complex; and strengthen construction supervision and control.
S4R4	Construction	Construction equipment should be serviced and replaced in a timely manner.

6. Conclusion

Based on the perspective of the correlation relationship of risk factors, this paper adopts the SNA to study the key risks existing in prefabricated building projects in the whole life cycle, and puts forward response strategies in a targeted manner. First, 12 risk factors in 4 different life cycle stages are identified through the collation of literature and the study of existing projects. Next, the SNA model was established and 5 key risk factors were identified through the network perspective. The key risk factors are poor design practical constructability, insufficient design integration, insufficient construction experience of on-site workers, poor construction practical feasibility, and insufficiently advanced construction equipment, and project managers should focus on the design phase and construction phase to strengthen the prevention, control and management of these risk factors. It is hoped that this can effectively block the transmission of risk and improve the risk management level of prefabricated building projects. Due to the limited research samples and the fact that only some of the factors in different life cycle stages were considered, this study still has some limitations. In the future, it is hoped that more risk cases can be selected for research.

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