Social Network Analysis of Risks in Prefabricated Building Projects

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Abstract

As a new construction method, prefabricated buildings are gradually changing the traditional construction model with their advantages of high efficiency and environmental friendliness. However, there are still many challenges in the process of its promotion, which requires the collaborative cooperation of various stakeholders. Social network analysis (SNA) provides an effective tool for studying the complex relationships among stakeholders. This study aims to use the social network analysis method to identify the key stakeholders in prefabricated building projects, analyze the characteristics of their relationship network, and provide a theoretical basis for optimizing project management and promoting cooperation. The main stakeholders in prefabricated building projects, such as the government, developers, design units, construction units, prefabricated component manufacturers, etc., are identified through literature research, expert interviews and other methods. Relationship data such as the interaction frequency, cooperation degree, and information exchange among stakeholders are collected through questionnaires, interviews, and other means. Social network analysis software (such as UCINET, Gephi, etc.) is used to construct the stakeholder relationship network model and conduct visual analysis.

Keywords

Prefabricated Building; Social Network Analysis Method; Stakeholders.

1. Introduction

Risk factor identification is a basic task for determining the potential risks of the research object, aiming to provide a solid basis for risk evaluation and control. In this process, common identification methods include Delphi method, literature research method, expert interview method, fault tree analysis method, risk checklist, and other means. Given the complexity and uniqueness of prefabricated building projects, the risk factors they face are also diverse, including policy changes, environmental changes, personnel management, capital flow, and other aspects. Therefore, this study combines the literature research method and the expert interview method. Based on the comprehensive literature analysis of relevant prefabricated building risks and prefabricated building research, we have expanded the general terms in a specific way to accurately define the risk elements required for this study. Through in - depth text mining and the supplementation of literature materials, we have sorted out a list of 32 risk factors in five categories as the preliminary risk identification list for subsequent research.

2. Construction of a Risk Analysis Model for Prefabricated Buildings based on Social Network Analysis

2.1 Analysis of Betweenness Centrality

Since the network model constructed in this study is a directed network model, in which there are clear sending and receiving relationship directions between nodes, the degree centrality of a point is correspondingly divided into two dimensions: out - degree and in - degree. This section will use absolute centrality as the specific indicator of the degree centrality of a point. Its calculation methods are shown in Formula 1 and Formula 2. Among them, C represents the absolute degree centrality, and Ci is used to represent the absolute degree centrality of a specific node i. This value is obtained by calculating the sum of the out - degree and in - degree of node i, so as to comprehensively reflect the degree of association of node i in the risk network.

$$C_i^o = \sum_{j \in A \text{且} i \neq j} R_{ij} \tag{1}$$

$$C_i^I = \sum_{j \in A \text{且} i \neq j} R_{ji} \tag{2}$$

The above calculation process can be carried out through the Ucinet analysis tool. After a series of operation processes such as "Network→Centrality→Degree", the analysis results of the degree centrality of the points in the risk network of this study can be obtained. In the risk network architecture, the out - degree and in - degree of a node (i.e., risk factor) carry different meanings. Specifically, if the out - degree of a certain risk factor is significant, it indicates that this factor has a significant potential impact on other risk factors in the network, and is highly likely to trigger the occurrence of other risks. It has obvious spontaneity in risk propagation and may play the role of a risk source.

2.2 Structural Hole Analysis

In this study, when measuring structural holes, the structural hole index system proposed by Burt is followed. This system covers four core measurement dimensions: efficiency, effective size, constraint, and hierarchy. Among them, the effective size is a key indicator for measuring the control power of a certain node over the entire network, and the constraint is used to evaluate the degree of dependence of this node on other nodes, both of which are of significant importance. Therefore, this study specifically selects the two indicators of constraint and effective size, combined with the node betweenness centrality analysis method described above, to conduct a comprehensive and in - depth analysis of the control ability of risk factors.

The interpretation of the effective size can be understood as the actual network size that a node can affect after removing the redundant elements in the network, that is, after removing the redundant connections in the individual network of a certain node. Specifically, the effective size of a certain node i can be calculated by the following formula:

$$\sum_i (1 - \sum_q p_{ia} m_{ia}), q \neq i, j \tag{3}$$

Among them, j represents all the points connected to i, q is a point other than i and j, represents the proportion of the indirect connection between point i and q, which is equal to the value of the relationship from j to q divided by the maximum value of the relationship from j to other points, representing the marginal strength of the relationship from j to q. And represents the redundancy between i and j. The "constraint" that a person receives refers to the ability of this person to use structural holes in his own network. Its calculation formula is as follows:

$$C_{ij} = (p_{iq} + \sum_{q} p_{iq} p_{qj}) \tag{4}$$

3. Case Analysis

To verify the applicability of this study in the risk assessment of the construction stage of prefabricated buildings, a testing center project located in Yun long District, Xuzhou City was selected as a research case. The total land area of this project is 20,029.67 square meters, and the total construction area is 48,165.57 square meters, including 35,675.83 square meters above ground and 12,489.74 square meters underground. In this building complex, Building B is a prefabricated building, consisting of 6 small single - body buildings. This building is a five - story building with a floor height of 5.5m and took 15 months to complete. The maximum prefabrication rate of a single unit exceeds 50%, and the prefabrication and assembly rate exceeds 60%. It innovatively uses a fully prefabricated concrete structure system and establishes a fully prefabricated design system for concrete - structure buildings with prefabrication and assembly as the core.

3.1 Construction of the Risk Network

A quality risk structure matrix is constructed based on the interview results, and the risk social network is drawn using Net draw in Ucinet6.0 software to visualize the risk structure matrix. Through Ucinet6.0 software, it can be calculated that the overall network density of this risk social network diagram is 0.201, tending to be medium. The risk complexity of the entire project is average, and the overall risk that the project manager needs to bear is at a medium - high level.

3.2 Construction of the Risk Network

Table 1. Analysis Results of Risk Factor Control Ability Index

Risk Factor	Betweenness Centrality of the Point	Effective Size	Constraint
S1R1	5.228	6.462	0.340
S1R2	1.464	5.444	0.389
S1R3	0.948	5.833	0.382
S1R4	0.000	4.313	0.443
S1R5	13.085	19.567	0.151
S2R6	0.518	5.278	0.371
S2R7	0.907	4.875	0.417
S2R8	2.214	8.367	0.262
S2R9	0.000	2.750	0.542
S3R10	3.418	9.700	0.253

By using the Ucinet software and following the established operation process, we can accurately calculate the betweenness centrality of each risk factor in the whole life cycle of the prefabricated building project, and further conduct structural hole analysis. The analysis results show that several key risk factors, such as S5R28, S6R34, and S1R5, occupy a high betweenness centrality position in the risk network structure, which clearly indicates that they have significant control and influence in the risk transmission path. These risk factors have a relatively large effective size and a low degree of constraint, thus highlighting their "bridge" role in the risk network. On the other hand, although risk factors such as S3R20 and S3R11 do not rank highly in terms of betweenness centrality, their effective size is also significant, and the degree of constraint is small, which implies that these risk factors also have non - negligible control potential in the network. Conversely, risk factors with low betweenness centrality, such as S3R15 and S4R24, show characteristics of small effective size, low ranking, and high constraint. These characteristics together indicate that their control ability in the risk network is relatively weak, and their impact on the risk transmission process is also limited. The analysis results of the risk factor control ability index are shown in Table 1.

3.3 Construction of the Risk Network

With the help of the Ucinet software, we finally determined that Blocks 1, 2, 3, and 4 are the core areas of the risk network. Within this core area, 15 risk factors, such as S1R1, S1R3, S5R26, S3R16, S3R15, S3R19, S3R14, S3R12, S1R5, S3R20, S3R11, S5R25, S5R29, S5R27, and S5R28, are regarded as key risk factors with significant and potential impacts.

This study used the methods of betweenness centrality and structural hole analysis to comprehensively evaluate the control ability of risk factors with the help of three indicators. The evaluation results show that risk factors with higher betweenness centrality, large effective size, and low constraint exhibit stronger control ability. Specifically, risk factors such as S5R28, S6R34, and S1R5 show significant control advantages in the risk network. In particular, factors like S6R34 and S1R5, due to their low constraint, are prone to forming structural holes and thus have strong control abilities. In addition, although S3R20 and S3R11 are not ranked among the top seven, their large effective size and small constraint also show strong control abilities. In summary, risk factors such as S5R28, S6R34, S1R5, S3R19, S3R16, S3R12, S3R18, S3R20, and S3R11 are regarded as key risk factors.

This study used the broker analysis method to systematically classify and count the risk factors and sorted them according to the frequency of occurrence of each factor. As a result, the key risk factors ranking in the top 30% were screened out, specifically: S1R5, S3R19, S3R18, S3R12, S3R11, S3R10, S3R20, S5R26, S5R27, and S5R25. On this basis, this study further analyzed these risk factors in depth and finally determined five core risk factors, namely S1R5, S3R11, S3R12, S3R20, and S3R19. In addition, five risk factors, S5R27, S3R18, S6R34, S5R29, and S3R14, are also regarded as key risk factors due to their high out - degree and in - degree characteristics.

Finally, through scientific data analysis methods, 8 key risk factors were finally determined, which are: investment exceeding expectations, construction period delay due to complex construction technology, construction cost exceeding expectations, insufficient communication and cooperation with design and supply units, inadequate control of materials and technical quality at key parts, failure to meet energy - saving and environmental protection standards, materials not meeting quality requirements, and changes in relevant standards and specifications,see Fig. 1.

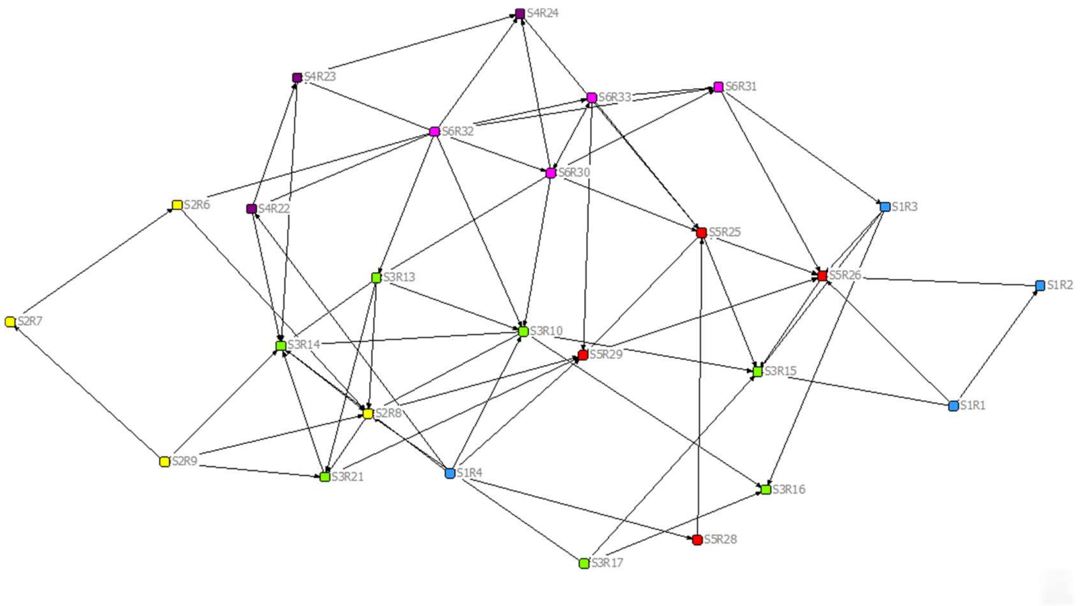

Fig. 1 Risk Network after Eliminating Key Risks and Risk Factors

4. Conclusion

This article used the risk network for an actual case to determine the key risk factors and propose measures to achieve the goal of reducing the overall project risk. However, the effectiveness of the theoretical response measures in practice is still unclear. In addition, this study aimed to quickly reduce the overall risk with the shortest control path for key risks and did not consider the marginal risk factors in the risk network. In actual projects, comprehensive prevention is required, with key control.

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