Research on schedule risk of prefabricated building project based on Social Network Analysis

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Abstract. As a new construction mode, prefabricated building plays an important role in promoting the industrialization of construction and realizing the industrialization and high-quality development of the construction industry. At present, prefabricated buildings are different from traditional construction forms in factory production, transportation, on-site assembly and other construction links, resulting in an increase in project schedule uncertainties, and traditional schedule risk management can no longer meet the development requirements of prefabricated buildings, so it is necessary to explore appropriate schedule risk management methods. Taking the construction project of a comprehensive teaching building in a university in Zhuhai as an example, this paper constructs a prefabricated building construction schedule risk grid model based on social network analysis, identifies key project schedule risk factors according to the analysis of social network related measurement indicators, and puts forward risk countermeasures.

Keywords: prefabricated building, Schedule risk, Social network analysis

1 INTRODUCTION

With the continuous expansion of the scale of prefabricated buildings, the project schedule management has been paid more and more attention. Compared with traditional buildings, prefabricated buildings have experienced unprecedented changes in the construction methods. Frequent interaction and communication between relevant project participants make the progress relationship increasingly complex. All parties lack experience in prefabricated building progress management, resulting in insufficient awareness of progress risk and increased uncertainty of the overall progress of prefabricated building projects [1], making risk management difficult.

The disadvantages of poor interoperability and real-time information accessibility of all parties involved exist in the progress management of prefabricated buildings, [2] The problem of "information island" is easy to occur in the management, resulting in various

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new progress risks. In recent years, domestic and foreign scholars have gradually increased their research on related schedule risks. CusBabic et al. [3] studied the integration of information flow related to supply chain and material management in prefabricated buildings, and proposed a theoretical model of technological innovation based on information mapping based on BIM technology. Li et al. [4] adopted a system dynamics approach to identify and study the potential impact of various risks on the construction project schedule by using Vensim software. Chen Nian et al. [5] established a risk network theoretical model by using structural equations under EPC mode, and used SEM methods to analyze the relationship between risks and determine the key schedule risk relationship. The above research provides beneficial reference for the construction schedule risk management of prefabricated buildings, but it fails to fully consider the dynamic change of project risk and the interaction between the relationship between participants and the schedule risk indicators, which requires in-depth research.

This paper intends to use Social Network Analysis (SNA) method to assess the schedule risk of prefabricated construction projects. Ucinet6.0 analysis software is used to identify key participants, analyze information flow and evaluate the effect of resource allocation, and assess their influence on the project schedule risk. [6] The project case is verified and corresponding schedule risk management strategies are proposed. It is hoped to provide new ideas and methods for the construction schedule management and risk control of prefabricated buildings.

2 Establishment of schedule risk assessment model based on SNA

2.1 Identification of risk relationship

According to the actual characteristics of the selected projects, this paper adopts the traditional experience-based method and combines the schedule risk factors identified by the theoretical model to identify the project stakeholders and their schedule risks. This paper mainly collects the required data by sending questionnaires and interviews to the participants of the project. These data include: project overview and characteristics; Key project stakeholders and their associated schedule risk factors; The interrelationship between schedule risk factors.

2.2 Establishment of risk social network

In view of the structure matrix of the progress risk interaction relationship obtained above, NetDraw software provided by Ucinet6.0 is used to draw the network relationship diagram. The density of grid segments in the diagram is ex-pressed by grid density, which refers to the proportion of the total number of actual line segments between each index to the total number of theoretical maximum line segments. The specific expression is:

$$D = \frac{L}{N(N-1)} \tag{1}$$

In formula 1, $\boldsymbol{D}$ is the network density; $\boldsymbol{L}$ is the total number of actual line segments; ***N*** indicates the number of indicators. If the network density is greater than 0.5, it indicates that the overall schedule risk is more complex, the relation-ship between each schedule risk factor is relatively close, and the degree of causality and interaction is relatively high. On the contrary, the risk is simpler.

3 Identification of risk relationship

3.1 Node centrality

Node centrality represents the number of connections between a node and other nodes in a social network, and the influence among risk factors is directional. There are nodes "In Degree" and "Out Degree". If the "Out Degree" of a risk factor is large and the "In Degree" is small, it means that the risk has a large influence on other risks, and there are many uncontrollable factors, so it should be avoided from the source. If the risk "In Degree " is large, the risk factor "Out Degree " is small, indicating that the risk factor is easy to be affected by other risk factors, but it is not easy to produce new risk factors, and the influencing risk factors should be controlled. In this paper, different risk management strategies are adopted according to the relative size (Degree difference) of node exit degree and entry degree. See (2) (3) (4) for relevant expressions.

$$d_r(r_i) = \sum X_{ji} \tag{2}$$

$$d_c(r_i) = \sum X_{ji} \tag{3}$$

$$\Delta d(r_i) = d_c(r_i) - d_r(r_i) \tag{4}$$

In equations (2) and (3), $d_r(r_i)$ is the node entry degree; *dc (ri)* is node output; *Xji* indicates the number of connections from risk indicator *Rj* to risk indicator *Ri. 0* or *1* can be used to indicate that there is no connection between nodes or that there is a connection between nodes. Equation (4)$\Delta d(r_i)$ is the node degree difference.

3.2 Betweenness

Intermediate centrality measures the important "Bridge" connection role played by a node, and it reflects the node If the control over the resource information of the whole system of the project is lost, the causal relationship between other nodes may no longer exist, that is, the impact transmission between risks will also disappear. The calculation of intermediate centrality generally uses the concept of geodesic, if there are three nodes *i, j* and *k*, g_{ij} represents the specific number of shortest paths (geodesics) between node *i* and node *j*, using *Qij (k)*Reflecting the intermediate centrality of the node, the specific number of shortest paths that exist between node *i* and node *j* and pass through node k is expressed by *gij (k)*. The calculation formula is shown in (5).

$$Q_{ij}(k) = g_{ij}(k)/g_{ij} \tag{5}$$

According to the definition of node centrality, the absolute intermediate centrality *(C_{ABK})* of node *k*, the position probability of geodesic between all node pairs of point *k* in the social network diagram is added, which is expressed by formula (6).

$$C_{ABK} = \sum_{i}^{n} \times \sum_{j}^{n} Q_{ij}\,(k), \quad i \neq k \neq j \tag{6}$$

If n^2-3n+2 represents the maximum value of absolute intermediate centrality, then the formula for calculating relative intermediate centrality is expressed by (7) as:

$$C_{RBK} = C_{ABK}/n^2 - 3n + 2 \tag{7}$$

The greater the value of intermediate centrality, the greater the influence on other nodes and the stronger the control ability of other resource networks. The more likely they are to be in a "Key" position in the overall social network.

3.3 Closeness

Closeness indicates how close a node is to other nodes. The calculation is also based on the concept of geodesics, and the proximity of nodes to the center is the reciprocal of the sum of all geodesics between nodes. Its calculation formula is shown in (8).

$$C_C(n_i) = \left[\sum_{j=1}^{g} d(n_i, n_j)\right]^{-1} \tag{8}$$

Where $d(n_i,n_j)$ represents the distance between n_i and n_j. The smaller the value of a node's Closeness, the more critical the node is in the social network and the less it is affected by other nodes in the network structure.

3.4 Determination of key quality risks

In this paper, the top 6 quality risk indicators in the ranking of Betweenness are directly regarded as key risks, and the risk indicators with high node centrality and Closeness are screened according to their risk values, and the indicators with the top 50% node centrality or Closeness and 50% risk value ranking are regarded as key risk indicators. The analysis process for critical risk identification is shown in Figure 1.

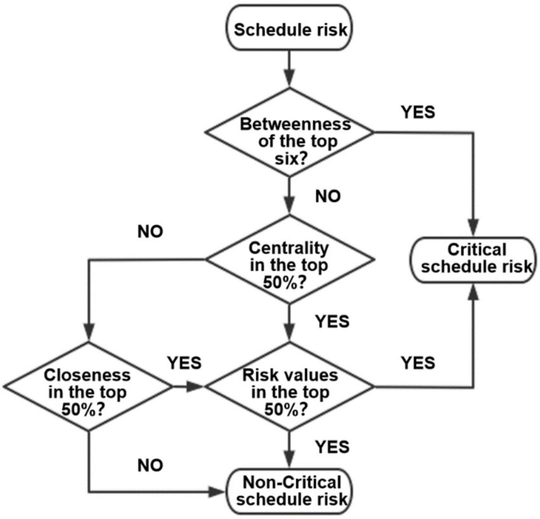

Fig. 1. Key schedule risk determination step diagram

4 EMPIRICAL ANALYSIS

4.1 Project Overview

Taking the comprehensive teaching building project of a university in Zhuhai as an example, this project has a construction area of 21056.48 m2, and is mainly based on prefabricated building structure, among which the single prefabricated rate is more than 60% and the prefabricated assembly rate is more than 72%. The author participates in the project management of the project, and uses SNA for risk prediction and assessment in progress management. The validity of the analysis is verified by the engineering implementation process.

4.2 Construction of risk social network

Risk index and schedule control participant identification are the basis of schedule risk assessment. Based on various stages of the whole production process of prefabricated buildings and guided by different types of schedule risks, this paper uses literature analysis to identify indicators that affect the comprehensive quality risk status of prefabricated buildings in the production and construction process, and revises the identified risk indicators by means of questionnaire sur-vey and expert interview. 19 main risk indicators composed of stakeholders' progress risk factors were obtained through the summary and sorting of data, as shown in Table 1.

Table 1. Prefabricated construction project schedule risk index system

NO.	Stake-holder	Work phase	Risk indicator
S1R1	proprietor	Design phase	Financing difficulties
S1R2			Inefficient information transfer with other stakeholders
S2R1	contractor	Design phase	Insufficient turnover of own funds
S2R2			Inefficient information transfer with other stakeholders
S2R3		Construction phase	Weak ability to respond to engineering design changes
S2R4			Internal and external organization coordination is poor
S2R5			The key technology system of prefabricated construction is immature
S2R6			The application of BIM, RFID in the prefabricated building system is not mature
S3R1	designer	Design phase	Engineering design changes frequently
S3R2			Drawing deepening lack of complete standardized design system
S3R3			Engineering design errors or defects
S3R4			The cooperation efficiency of each professional design unit in the design stage is not high
S3R5			Did not fully communicate with the constructor in the early stage of design
S4R1	manufacturer	Component manufacturing stage	And the information asymmetry between the designer
S4R2			Prefabricated components were delivered late
S4R3			The production process system of prefabricated components is not standard
S5R1	carrier	Transport stage	Low transportation and turnover efficiency
S6R1	government	Design phase	Low approval efficiency
S6R2		Construction phase	Relevant policies, standards and technical systems are not perfect

NetDraw in Ucinet6.0 software was used to draw the risk social network of a comprehensive teaching building project of a university in Zhuhai High-tech Zone, and the risk structure matrix was visualized, as shown in Figure 2.

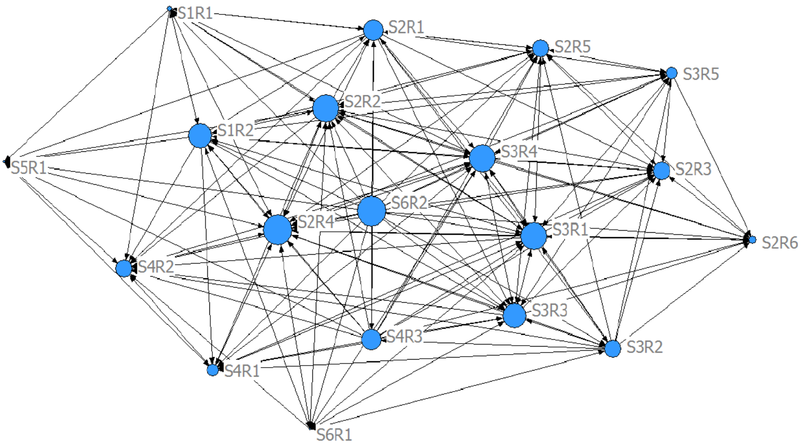

Fig. 2. Risk grid diagram of the project schedule

In Ucinet6.0 software, Network→cohesion→density is selected successively, and the number of edges of this item is 186. The network density is 0.5439, tending to the medium level of 0.5, and the risk complexity is medium. The project contractor should pay attention to the project schedule risk and do a good job in the dynamic control of the schedule risk.

4.3 Schedule risk network analysis results

Based on the risk structure matrix, Ucinet6.0 software is used to calculate the node centrality, intermediate centrality and proximity centrality of each risk index, as shown in Table 2.

Table 2. Risk grid analysis table of prefabricated construction project schedule

NO.	OutDegree	InDegree	Difference	Betweenness	Closeness
S6R2	18.000	0.000	9.000	0.000	5.263
S1R2	14.000	9.000	5.000	5.704	66.667
S4R3	13.000	2.000	11.000	0.767	36.735
S2R2	13.000	13.000	0.000	15.104	78.261
S3R1	13.000	14.000	-1.000	19.351	81.818
S2R4	12.000	18.000	-6.000	40.385	100.000
S3R4	12.000	13.000	-1.000	7.013	78.261
S3R2	12.000	5.000	7.000	17.623	52.941
S3R3	12.000	12.000	0.000	11.075	75.000
S2R1	10.000	8.000	2.000	7.816	64.286
S2R5	10.000	13.000	-3.000	10.324	78.261
S1R1	9.000	5.000	4.000	1.097	58.065
S3R5	8.000	10.000	-2.000	1.390	69.231

S6R1	8.000	8.000	0.000	4.754	64.286
S4R1	7.000	10.000	-3.000	8.867	69.231
S2R6	5.000	9.000	-4.000	0.744	66.667
S2R3	4.000	14.000	-10.000	1.661	81.818
S5R1	3.000	9.000	-6.000	0.533	66.667
S4R2	3.000	14.000	-11.000	1.793	81.818

4.4 Key schedule risk identification and coping strategies

Firstly, all indicators of social network are analyzed comprehensively, and the key progress risk factors are identified as far as possible from the multi-dimensional indicators. Then the corresponding control strategy is proposed by analyzing the influence and mechanism of these key schedule risk factors. Ac-cording to the above social network analysis data, it can be seen that the key schedule risks analyzed by various indicators are not completely consistent. By integrating all indicators, the schedule risks are divided into four levels, as shown in Table 3.

Table 3. Key schedule risk identification and analysis table

Level	**Grid analysis**	**Material schedule risk**	**Solution strategy**
1	Out Degree is large, In Degree is small, Betweenness is low, Closeness is high	S3R1 (Engineering design changes frequently) S3R4 (The cooperation efficiency of each design unit is not high) S3R3 (The standardized design system is incomplete) S3R2 (Rework design)	This kind of risk is easy to induce the occurrence and emergence of other risks, located at the top of the risk network chain, should focus on controlling its own probability.
2	Out Degree is large, In Degree is small, Betweenness and Closeness is high	S1R2 S2R3 (Low efficiency of information transfer with stakeholders) S6R2 (Policies, standards and technical systems are not perfect)	Such risks not only easily lead to other risks, but also affect the transmission of the relationship between other risks, and have a communication effect on the transmission of risks, so the management of such risks should be focused on.
3	Out Degree is small, In Degree is large, Betweenness and Closeness is high	S2R2 (Change of project scope) S2R5 (Poor organization and coordination) S2R6 (The key construction technology system such as prefabricated component installation, hoisting and joint connection is not mature)	This kind of risk plays a key role in the network bridge and bond, and has a strong influence and control in the risk network, and its small changes will cause large fluctuations in the overall risk.
4	Out Degree is small, In Degree large is, Betweenness is low, Closeness is high	S2R4 (The ability to respond to engineering design changes is weak) S5R1 (Low efficiency of information transfer with stakeholders) S6R1 (Low approval efficiency) S4R2 (Rework production)	Risk accumulation and evolution, the impact on other risks is small, do not need to invest too much effort, can be from the source of risk or reduce the loss of risk after the occurrence of risk management.

5 Conclusions

As a new building model, prefabricated building plays an important role in promoting the industrialization of construction and the high-quality development of construction industry. However, it is very different from the traditional construction method, which leads to the complexity of project schedule management. It is very important to identify risks effectively and avoid risks reasonably. Through literature review and expert interview, this paper determines the risk factors of prefabricated construction project schedule. The risk network model of prefabricated building project construction schedule is established by using Ucinet6.0 software. Taking the construction project of a comprehensive teaching building in a university in Zhuhai as an example, the theory is verified, and the relevant indicators of risk network are analyzed by social network analysis method, key schedule risks are screened, and corresponding risk management strategies are proposed. The research shows that the schedule risk social network model constructed in this paper has certain guiding significance for most prefabricated construction projects.

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