Analysis of the Schedule Risk of Prefabricated Buildings Based on ISM and Research of Transfer Path

Xiaobo Shi [1], Chenchen Liu [1], Wanying Liu [1*], Fang Shen [1], Jiayan Chen [1], Kunkun Ma [1]

[1] *School of Mechanics and Civil Engineering, China University of Mining and Technology, Jiangsu Province, Xuzhou, China.*

Abstract

Project schedule management is an important part of prefabricated construction project management. General contracting is an effective way to promote the development of prefabricated construction. However, at present, from the perspective of general contracting, the risk factors affecting the project progress of prefabricated buildings are not clear, and the relationship between risks is not known. The purpose of this study is to study the composition, hierarchical structure and transmission path of schedule risk factors of prefabricated construction in general contracting mode, so as to help the general contractor formulate effective schedule risk avoidance measures. This study uses grounded theory to obtain 22 risk factors that affect the progress of assembly building projects, and the data are from expert interviews. Using Delphi method and interpretative structural modeling (ISM), these factors are divided into seven levels, and the ISM model of schedule risk factors is constructed. The research shows that there are 60 progress risk transmission paths, and four progress risk transfer chains are obtained. This paper also further analyzes and puts forward suggestions to avoid risks for each level.

Keywords: Prefabricated Buildings; Schedule Management; Risk Factors; General Contracting Mode.

1. Introduction

A prefabricated building is a building assembled on a site with prefabricated parts. In essence, prefabrication is "a manufacturing process, generally taking place at a specialized facility, in which various materials are joined to form a component part of the final installation" [1]. Compared with traditional buildings, prefabricated buildings have the advantages of improving construction quality, shortening the construction period, saving labor cost, saving resources and energy and reducing construction pollution [2], which is one of the characteristics of a broader concept of industrialization in the building industry [3]. At the same time, the construction process of prefabricated buildings is complex and highly connected, and the project participants are numerous and need to cooperate closely, which makes it difficult for the owner to manage the work, and it is particularly critical for the owner to choose the contracting mode.

The general contracting mode refers to the enterprise entrusted by the owner to undertake the general contracting of the project, in accordance with the contractual agreement to carry out the whole process or several stages of the project survey, design, procurement, construction, and trial operation. At present, the general contracting mode of engineering is generally recognized as an effective way to develop prefabricated buildings. Under the general contracting mode, the management experience and main tasks of the general contractor can be brought into full play, , meet the requirements of systematic and integrated management of prefabricated buildings, fill the requirements of quality and performance to the maximum extent, and improve the efficiency of project construction [4].

However, the development of prefabricated buildings under the general contracting mode is still in the exploration stage, and its corresponding management mode is not perfect, which leads to the difficulty of exerting the advantages of the prefabricated construction schedule, such as low controllability of project schedule, frequent delay of schedule and even larger construction period than traditional construction. Scheduling involves the important and complex process of coordinating activities in construction projects [5]. Progress management, as a critical task of project management [6], is one of the indicators to directly measure and evaluate the success or failure of the project. Therefore, fully and systematically identifying the risk factors of assembly construction schedule under the general contracting mode, clarifying the relationship between factors, and studying the transmission path of risk factors can effectively assist managers to make objective and scientific decisions and improve the management level of assembly construction schedule under general contracting mode.

The remaining chapters of this paper include literature review, research methods, research process, research results and discussion, and conclusion. The literature review mainly reviews the scholars' research on construction schedule risk. The next part introduces two research methods: grounded theory and interpretative structural modeling (ISM). Through these methods, the research process is shown in detail. Identification of 22 risk factors and 60 risk transmission paths are introduced in the fourth section. Next, this paper analyzes the importance of all influencing factors at different levels of the explanatory structure model. Finally, the last section summarizes the research.

2. Literature Review

Previous studies have examined schedule risk from various perspectives, such as factor identification, mechanism of factors schedule delay prediction model and so on. Scholars usually introduce new theories or methods to study construction schedule risk innovatively. The common research methods include decision-making trial and evaluation laboratory (DEMATEL), analytic network process (ANP), bayesian network (BN), system dynamics (SD), etc. Luu et al. [7] identified the schedule risk factors of project, and used Bayesian belief network (BBN) to quantify the probability of construction project delay. The result of sensitivity analysis indicated that construction delay is extremely sensitive to the factors 'shortage of materials', 'defective construction work ' and ' slow site handover'. Daniel [8] evaluated the viability of using fuzzy mathematical models for determining construction schedules and for evaluating the contingencies created by schedule compression and delayed due to unforeseen material shortages. Bi et al. [9] applied the principal-agent theory to build a two-level principal-agent schedule risk control model for information technology outsourcing (ITO) projects. The simulation results illustrate that the two-level principal-agent model can largely improve the completion probability and reduce the duration of an ITO project, thereby achieving the objective of effectively controlling the schedule risk ITO. Chen et al. [10] develop a novel Bayesian Monte Carlo simulation-driven approach for construction schedule risk inference of infrastructures. In order to study the dynamics and uncertainty of risk, Xu et al. [11] pioneers a combined SD and DES model for simulating the underlying schedule risks. DES models a system to reveal the construction process, resource usage, and any other micro-level dynamic behavior, while SD carefully deals with the complex problems infrastructure project schedule from the perspective of a system.

In the research of prefabricated building construction schedule risk, Li et al. [12] applied system dynamics to recognize and investigate the potential effect of various risks on the scheduling of prefabrication housing construction projects through the employment of the VENSIM software package. Arashpour et al. [13] shed light on dynamics of risk and uncertainty in hybrid construction projects. The research suggests that risk of late completion in these projects intensifies as a result of uncertainty combination in off-site and on-site construction. Project size and work quantities, organization's risk appetite, resource availability, and workflow variability are contributors to the risk of late completion in hybrid construction projects. Based on the 24 factors identified in the literature review, Ji et al. [14] adopted the decision-making trial and evaluation laboratory (DEMATEL) model and analytic network process (ANP) method to quantify the cause-and-effect relationships and prioritise the key delay factors in terms of their importance in the construction of prefabricated buildings. The results reveal that the issue of inefficient structural connections for prefabricated components is found to be the most significant factor. Zhao et al. [15] combined SD (System Dynamics) and BP (Back Propagation) neural network, put forward a schedule delay prediction model system, which can provide the key information for controlling the delay effects of risk-related factors on scheduling in prefabricated construction. Tokdemir et al. [16] analyzed the relationship between schedule risk in the process of production and assembly, and finally quantified the delay risk of the project by Monte Carlo simulation.

A large number of risk analysis methods are adopted in the above research, which provides a tool for an in-depth and comprehensive understanding of the construction schedule risk of prefabricated buildings. But there are still some limitations. Firstly, the research is mainly based on the overall perspective of the project or the perspective of the owner. No research has focused on the perspective of the general contractor, and the general contractor is the main body bearing the risk. Secondly, previous studies focused on the importance ranking or relationship of schedule risk factors, and did not deeply discuss and analyze the hierarchical relationship between risk factors and the communication path between risks. Therefore, it lacks a comprehensive understanding of the risk relationship, and has not focused on putting forward risk avoidance measures or suggestions, so it is impossible to improve the level of schedule management from the

perspective of risk control. In order to fill this research gap, this paper aims to obtain the set of factors affecting the construction schedule risk of prefabricated buildings from the perspective of the general contractor through grounded theory, and use ism method to analyze the transmission path and mechanism of construction schedule risk of prefabricated buildings. On this basis, the basic and direct factors affecting the construction schedule risk of prefabricated buildings are identified, which provides targeted objectives for the construction schedule risk management of prefabricated buildings under the general contracting mode.

3. Research Methods

3.1. Identification of Construction Schedule Risk Factors of Prefabricated Buildings

This study adopts the qualitative research method of grounded theory. Through face-to-face and online interview, the interviewees were interviewed in depth according to the interview outline to obtain the original data of root coding. After that, the risk factors of prefabricated building construction schedule are extracted through open coding, spindle coding and selection coding, which lays the foundation for analyzing the hierarchical structure and transmission mechanism of risk factors.

3.2. Division of Risk Hierarchical Structure

An interpretative structural modeling (ISM) is used to study the hierarchical relationship of risk factors of the construction schedule under the project contracting mode. ISM is suitable for this research because it analyses the interrelationship among the variables of a specific problem based on experts' judgments [17]. This helps to impose order on, and direction to, the relationships among elements in a system, so that their influence can be analyzed [18]. ISM can clearly show the hierarchical relationship among system elements, and it is helpful to expose the relationship and mechanism of the risk factors of prefabricated construction progress, so as to guide the formulation of schedule risk response strategy and improve the level of schedule management. The flow of using ISM to analyze problems is shown in Figure 1.
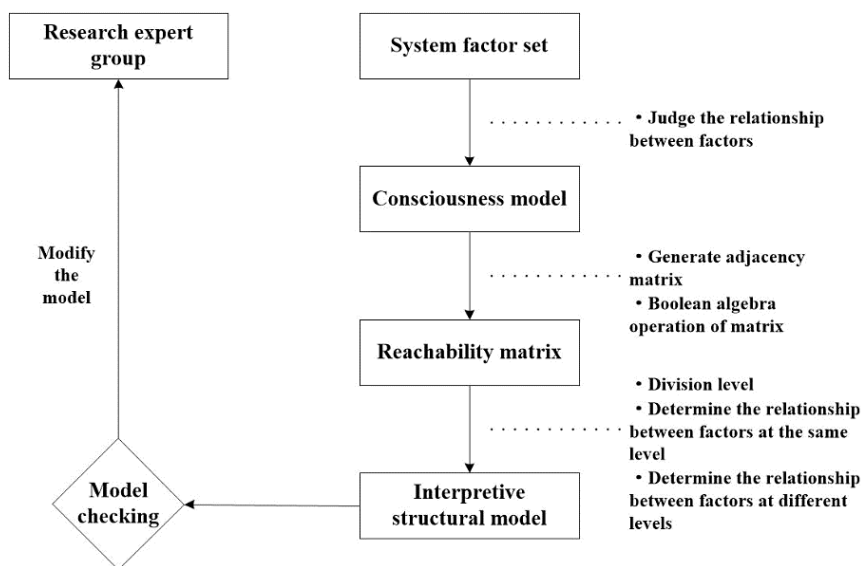

Figure 1. Flowchart of ISM

Step 1: Identify the factor set [19]. Combined with the research objectives and objects, the set of factors affecting the research object is determined, which is represented by S, and the factors in the factor set are represented by Si.

Step 2: Build an adjacency matrix. In order to get the relationship between the factors, expert interviews can be used to collect data. On this basis, through certain rules, these relations between factors are transformed into the expression of adjacency matrix. Assume that the adjacency matrix is A= $(a_{ij})_{n \times n}$, which means that there are n factors in the system, then define:

$$a_{ij} = \begin{cases} 1, & S_i \text{ has effect on } S_j \\ 0, & S_i \text{ has no effect on } S_j \end{cases} \tag{1}$$

Step 3: Calculation of reachable matrices. The direct influence relationship between factors can be expressed by adjacency matrix, and the indirect influence relationship between factors can be obtained by Boolean algebra operation on adjacency matrix, which can be expressed by reachability matrix. Assume that the reachable matrix is M, then its calculation formula is as follows:

$$(A + I) \neq (A + I)^2 \, ... \neq (A + I)^k = (A + I)^{k+1} = M \tag{2}$$

I is the unit matrix, $(A + I)$ represents that the adjacency matrix becomes a matrix with its own causality and k is the number of operations.

Step 4: Divide the hierarchy. For the reachable matrix M factor S_i, let its reachable set be $R(S_i)$, and the antecedent set be $A(S_i)$. If there is an intersection between the reachable set and the antecedent set, the intersection is called the common factor set, which is represented by $C(S_i)$. When $C(S_i)=R(S_i) \cap A(S_i)=R(S_i)$, S_i representation factor for the highest level factor in the model. In this paper, the top-level factors are constantly identified to divide the hierarchy, used $L_{(n)} = [L_1, L_2, ..., L_k]$ (k=1, 2, ..., n) to represent.

Step 5: Construct ISM models. The multi-level hierarchical directed graph can be drawn according to the influence relation and hierarchy of factors expressed in the M of reachable matrix to form the ISM model.

Step 6: Analyze the progress risk transfer path. Analysis ISM model reveals the transmission path of progress risk, and then predicts the possible transmission path of progress risk in the future, so that managers can make timely decisions to cut off the risk transmission path.

4. Analysis of the Schedule Risk of Prefabricated Buildings and Transfer Path

4.1. Establishment of a Schedule Risk Factor Set

In order to ensure the completeness, representativeness, and reliability of the number obtained from the interview, this study interviewed five industry experts and researchers in the field of prefabricated buildings and progress risk, as well as 20 employees of each participating enterprise, and went deep into Shandong, Anhui, Jiangsu, Guangzhou and other assembly construction projects to carry out research, the specific participants include senior managers and major technical workers in each enterprise.

According to the interview records of 25 experts, through the three processes including open coding, spindle coding and selection coding, the relevant risk factors are extracted. Table 1 lists 22 risk factors of the assembly construction schedules under the general contracting mode [20], including technical scheme, project environment, personnel factor, component factor, equipment factor and construction management 6 parts, which constitute the risk factor set $S=\{S_1, S_2, ..., S_{22}\}$.

Table 1. Schedule Risk Factors for Prefabricated Construction under General Contracting Mode

Category	Factors	Interpretation
Technical program	S_1 Design scheme	Overall content planning and design of prefabricated construction projects
	S_2 Component deepening design scheme	Design of Separation and Connection of Prefabricated Building Components
	S_3 Production program	Production Units Specific to Assembly Construction Projects Component production program developed by requirements
	S_4 Transport program	Transportation time, route, route, Order, component protection measures
	S_5 Construction program	Implementation plans for prefabricated building projects, Including personnel arrangement, hoisting scheme, technical scheme, etc.
Project environment	S_6 Technical environment	Development and application of new technologies such as BIM、RFID、ERP
	S_7 Environmental Policy	National and local environmental policies
	S_8 Degree of perfection of standards and norms	Standards and Regulations for Assembly Construction Industry
Personnel factors	S_9 Design level	Designers' level and capability in prefabricated building design
	S_{10} Component production experience	Production level and experience of assembly component manufacturers
	S_{11} Experience in general contracting projects	Experience in prefabricated construction project management for general contracting units
	S_{12} Technical expertise	Professional competence of technical person in charge of industry and field technician
	S_{13} Technical competence of workers	Operational proficiency of all types of workers in assembly construction techniques
Component factors	S_{14} Component approach time	Whether the prefabricated components can arrive at the construction site on time as required
	S_{15} Component quality	Prefabricated components pass quality inspection before installation
Equipment factor	S_{16} Equipment efficiency	Production efficiency of equipment during prefabricated building construction
	S_{17} Equipment selection	Reasonable selection of equipment during assembly construction

Construction management	S$_{18}$ Construction technology	Before the start of the assembly project, the professional and technical personnel shall give special technical instructions to the construction personnel
	S$_{19}$ Construction process arrangement	The assembly construction task is divided into several construction processes, And the construction procedure according to reasonable smooth lap arrangement
	S$_{20}$ Project management capacity	Ability to plan, coordinate and manage issues effectively
	S$_{21}$ Coordination of communication management	Effective communication and coordination among project participants
	S$_{22}$ Engineering change	Approved installations during construction of assembly construction projects Modification, improvement and optimization of drawings, plans, etc.

4.2. Construction Schedule ISM Model of Prefabricated Buildings under General Contracting Mode

ISM is used to solve complex problems by developing a hierarchical structure that provides a systematic basis for managerial decisions. However, expert judgments must be obtained to format the structure, and experts must assess the relationships among the proposed criteria via linguistic variables [21]. On the basis of the set of schedule risk factors shown in Table 1, seven experts from different fields of prefabricated construction were organized to form an expert group to discuss the direct influence relationship between schedule risk factors by using the Delphi method. According to the discussion results of the expert group, the direct influence relationship between the risk factors of prefabricated building construction schedule is finally clarified, and the risk factor influence matrix is created, as shown in Figure 2. A means that S$_j$ will directly affect S$_i$, V means that Si will directly affect S$_j$, X means that S$_i$ will directly affect S$_j$ and S$_j$ will react on Si, and O means that S$_i$ will not directly affect S$_j$ and S$_j$ is the same.
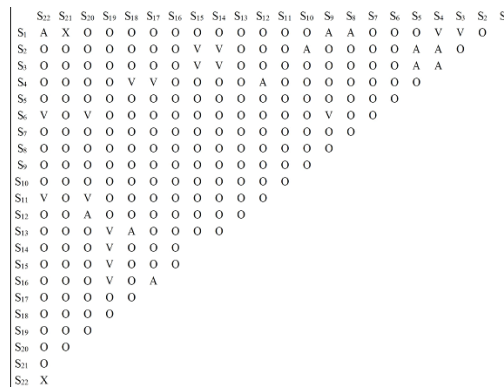

Figure 2. Influencing relation matrix of risk factor

According to the transformation rules in Table 2, the correlation between risk factors determined by experts is transformed into risk factor adjacency matrix A, as shown in Figure 3.

Table 2. Conversion rules

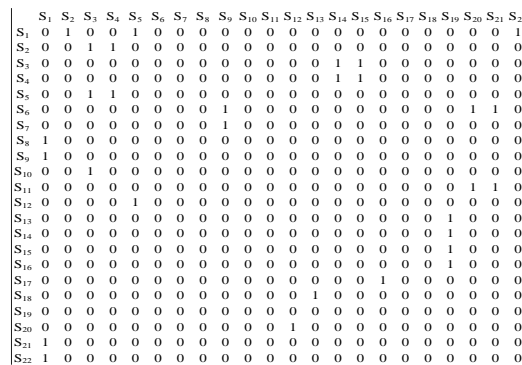| Index Value	i=j	A	V	O	X
aij	0	0	1	0	1
aji	0	1	0	0	1

Figure 3. Adjacency matrix A

The adjacency matrix represents the direct influence relationship between the factors, but the indirect influence relationship between the factors cannot be reflected. With the help of MATLAB software, the reachable matrix M is

obtained by calculating the adjacency matrix with Equation 1, and the elements in the reachable matrix reflect all the influence relations among the factors. The progress risk reachable matrix is shown in Figure 4.

	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}	S_{16}	S_{17}	S_{18}	S_{19}	S_{20}	S_{21}	S_{22}
S_1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	1
S_2	0	1	1	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0
S_3	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0
S_4	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0
S_5	0	0	1	1	1	0	0	0	0	0	0	0	0	1	1	0	1	1	1	0	0	0
S_6	1	1	1	1	1	1	0	0	1	1	0	0	0	1	1	0	0	0	1	1	1	1
S_7	1	1	1	1	1	0	1	1	0	0	0	0	0	1	1	0	0	0	1	0	0	0
S_8	1	1	1	1	1	0	0	1	0	0	0	0	0	1	1	0	0	0	1	0	0	1
S_9	1	1	1	1	1	0	0	0	1	0	0	0	0	1	1	0	0	0	1	0	0	1
S_{10}	0	0	1	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	1	0	0	0
S_{11}	1	1	1	1	1	0	0	0	0	0	1	0	0	1	1	0	0	0	1	1	1	1
S_{12}	0	0	1	1	1	0	0	0	0	0	0	1	0	1	1	0	0	0	1	0	0	0
S_{13}	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
S_{14}	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
S_{15}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0
S_{16}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
S_{17}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0
S_{18}	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0
S_{19}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
S_{20}	0	0	1	0	0	0	0	0	0	1	0	1	0	1	1	0	0	0	1	1	0	1
S_{21}	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	1	1
S_{22}	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	1

Figure 4. Accessible matrix M

In this paper, the highest level factors are constantly identified to divide the hierarchy, and finally, the risk factors of the construction schedule of the assembly construction under the general contracting mode are divided into seven levels. The ISM model is drawn M combining the divided hierarchy with the reachable matrix, where the values in the reachable matrix M correspond to the influence relationship between the factors in the model directed graph. Construction schedule risk factors ISM model of assembly construction under general contracting mode is shown in Figure 5.
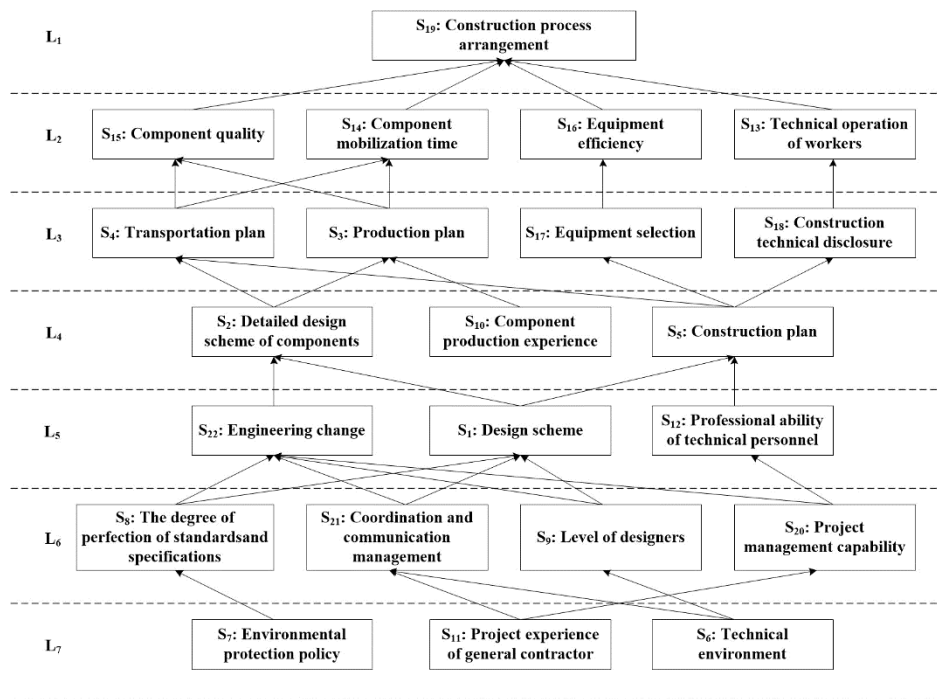

**Figure 5. Progress risk factor ISM model**

According to the ISM model, progress risk factors can be divided into direct factors, indirect factors, and fundamental factors. The direct factor is the first layer of the model structure, the indirect factor is two to five layers, and the fundamental factor is the sixth and seventh layers.

## 4.3. Risk Transmission Path Analysis

Based on the analysis of progress risk factors ISM model, four kinds of risk transfer chains are obtained as shown in Figure 6, including technology environmental risk transfer chain, general contract project risk transfer chain, environmental protection policy risk transfer chain, and component production experience risk transfer chain. A total of 60 risk transfer paths were formed, including 26 technical environmental risk transfer paths, 18 general contracting project experience risk transfer paths, 14 environmental protection policy risk transfer paths, and 2 component production experience risk transfer paths.
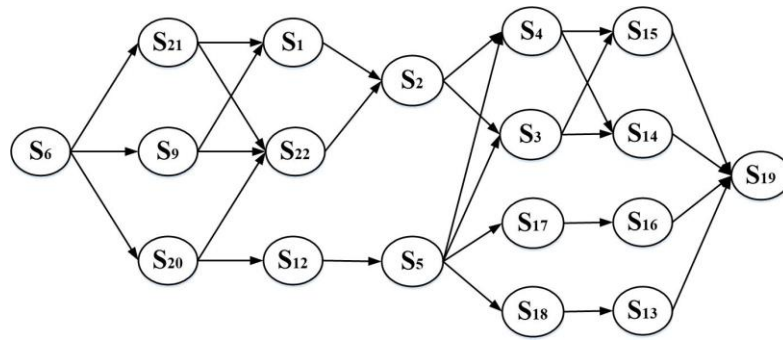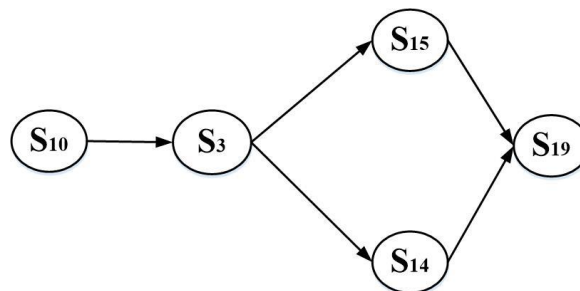
(a) Technology environmental risk chain
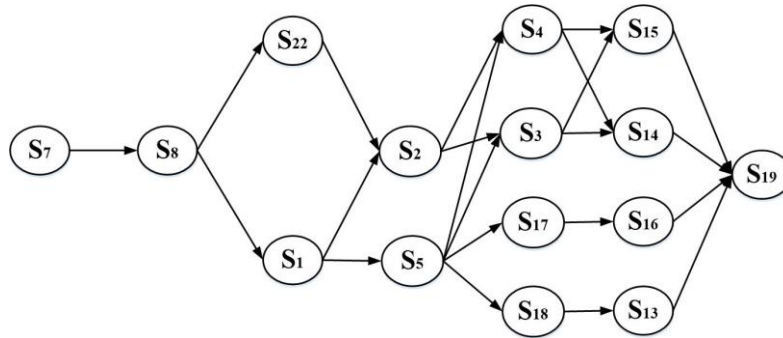
(b) Environmental policy risk chain
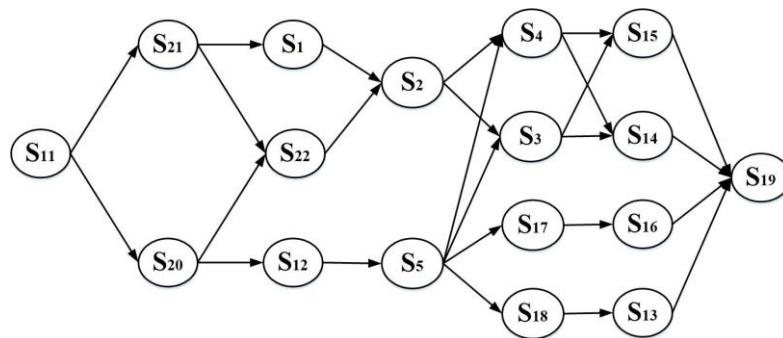
(c) General contracting project experience risk transfer chain

(d) Component production experience risk transfer chain

Figure 6. Progress risk transfer path

From the progress risk transfer chain, it can be seen that the technical environment, environmental protection policy, general contracting project experience, and component manufacturer experience are the source risks that cause the construction schedule risk of prefabricated buildings. These risk factors transfer the risk step by step along its inherent path, forming different risk transmission lines until it reaches the end of the risk of the construction schedule of the assembly construction under the perspective of the general contractor of the project. It can be seen that the risk factor of the construction schedule of prefabricated buildings is a complex system in which all the factors are in unstable change and contact state. The internal factors of the system always interact with each other and then influence each other. The relationship between the risk factors is complex, and the hierarchical structure relationship between the factors is

obtained through analysis, and the risk factors of each level are directly affected by their lower level factors. Apart from this, not all factors directly affect the construction schedule of prefabricated buildings, but it is possible to gradually infiltrate through different risk transfer routes and act in a way of coupling between factors. In the process of risk transmission, it is possible to have different effects because of different paths.

5. Results and Discussion

From the above research, it can be seen that there are many risk factors affecting the construction progress of prefabricated buildings, and there are complex relationships among them. The project management personnel of the EPC unit can clearly and intuitively understand the hierarchical relationship between these risk factors and take the initiative to develop relevant preventive measures, which is beneficial to reduce the schedule delay of prefabricated building construction. According to the comprehensive analysis of figure 5, it can be concluded that:

- EPC project experience (S_{11}), new technology (BIM, RFID, etc.) application (S_6) and Environmental protection policy (S_7) are at the bottom of the interpretive structural model, which are the fundamental factors affecting the risk management of prefabricated construction schedule, that is, the fundamental reason affecting the project duration.

- The 3-6 layers of ISM are indirect factors. Indirect factors are derived from fundamental factors. Although they will not directly affect the progress of prefabricated construction projects, they promote the direct factors.

- Construction process arrangement (S_{19}) are at the top level of interpretative structural model, and component quality (S_{15}), component mobilization time (S_{14}), equipment efficiency (S_{16}) and technical operation of workers (S_{13}) are at the second level of interpretative structural model, which are the direct factors affecting schedule risk, that is, the direct cause of schedule delay.

In the previous research focusing on the influencing factors of progress, most scholars pay more attention to the identification and weight of factors. For example, Ji et al. concluded that inefficient structural connections is considered the most significant indicator due to having the highest global weight. Moreover, handling components, lack of communication among participants, low productivity, and the inadequate worker experience are also relatively important factors. From the perspective of general contracting, this study creatively obtains the construction schedule risk factors that are slightly different from previous studies. At the same time, through the detailed analysis of the factor relationship of ISM model and combined with the construction practice, the causal relationship between the factors can be obtained, so that the risk can be avoided.

For the general contractor, it is necessary to have certain experience and management ability of prefabricated construction project, so as to do a good job in the progress management of the whole project. The use of BIM, RFID, EPR and other emerging industry technologies can greatly improve the project management efficiency of the general contractor. At present, countries pay more and more attention to environmental protection. Protecting and improving the environment can not only make the staff have a good mood environment, but also improve the work efficiency and quality. In the process of prefabricated building construction, the general contractor should not only complete the work with quality and quantity, but also pay attention to environmental protection, such as doing a good job in the sanitation and epidemic prevention, noise control, waste disposal, plant capacity management and material management of the construction site.

It can be seen from the figure that the perfection degree of design standards and specifications, the coordination and management ability of general contractor and the level of designers will affect the rationality and applicability of design scheme for prefabricated building components. Therefore, in order to comprehensively consider whether the design scheme can be applied to the component production, transportation and construction stage, the general contractor needs to coordinate with the designers, component manufacturers and construction unit technicians to communicate in advance to understand the requirements and constraints of production and construction on design. As the prefabricated architectural design is more complex and precise than the traditional design, it not only puts forward higher requirements for the level of designers, but also requires the cooperation and cohesion of various professional designers, considering whether the final scheme after the synthesis of various professional designs will encounter collision and conflict. The prefabricated building construction management involves many aspects, complicated process and a large amount of resources. In order to avoid process confusion and low construction efficiency, the general contractor should comprehensively consider various factors, and reasonably arrange the personnel, materials and machines to ensure the smooth progress of construction.

Design scheme (S_1), professional ability of technical personnel (S_{12}), engineering change (S_{22}) are located at the fifth layer of the interpretive structural model. The component production experience (S_{10}), detailed design scheme of components (S_2), construction plan (S_5) are located on the fourth floor of the interpretive structural model. Because the prefabricated components production and site construction of prefabricated buildings are separated, the coordination of subsequent production and construction process should be integrated in the design process. Therefore, whether the

design scheme is considered comprehensively and reasonably will directly affect the prefabricated construction scheme and component fabrication drawing scheme, and then affect the rationality and realizability of transportation scheme and production plan. It can be seen from the figure that the design scheme and design change have a strong connection relationship and mutual influence. The incomplete consideration of the design scheme in the early stage or more errors in the drawings will lead to design changes in the construction process, and these changes will inevitably affect the design documents, drawings, schemes, etc. In the prefabricated construction mode, design changes cannot be completely solved in the construction site, which involves the production of components, transportation, on-site hoisting construction and other stages, and has a great impact on the construction progress. In the construction stage, the professional ability of technical personnel directly affects the formulation and implementation of the technical scheme of the whole project, so as to have an impact on the quality of the project. The technician is responsible for the implementation of the technical scheme, construction steps, professional technical disclosure and other key works in the project. If his professional knowledge level and technical reserves do not meet the requirements, it will directly affect whether the prefabricated construction scheme can be successfully realized, and then affect the construction progress. With the increasing number of prefabricated buildings, component factories will not keep up with the market demand because of their own capacity. In this case, an experienced component manufacturer is very important, which has a direct impact on how to arrange the production plan and schedule, supply goods on time, and avoid adverse impact on the construction progress.

Transportation plan (S_4), production plan (S_3), equipment selection (S_{17}) and construction technology disclosure (S_{18}) are located in the third floor of the interpretative structural model. Component quality (S_{15}), component mobilization time (S_{14}), equipment efficiency (S_{16}) and technical operation of works (S_{13}) are located in the second layer of interpretive structural model. Whether the component production plan is in strict accordance with the specification requirements, whether the production process selection is reasonable, whether the technical preparation is sufficient, whether the transportation plan takes into account the component protection measures, the selection of transportation vehicles and the transportation route planning, etc., will directly affect the quality of the component and the time of the component entering the site. If the components to be hoisted and connected in the construction site have not entered the site or have quality problems, the construction process will not be carried out, and even cause the phenomenon of workers' idleness. The hoisting and installation of components run through the whole construction period of prefabricated building project. The weight of components is large, and the lifting position is generally high, so the site construction conditions should be considered to select the appropriate equipment, so as to avoid the equipment status problems caused by the insufficient bearing capacity of the selected lifting equipment, which will lead to the inaccurate lifting position, the inclination of prefabricated components and other problems, and seriously affect the construction progress of prefabricated buildings. Construction technology disclosure is an essential work in the construction stage of any project, which is the expansion and supplement of the construction scheme, and will greatly affect the technical operation ability of workers. If the construction workers do not fully understand the construction technology and process of prefabricated buildings, it will lead to the subsequent construction cannot be carried out in strict accordance with the construction specifications, and the function of the components is not fully understood, which will lead to the wrong installation, and lead to repeated hoisting and delay the progress.

Construction process arrangement (S_{19}) is at the top level of interpretative structural model. If the construction process is not properly arranged and the sequence and overlap of the process are not properly handled, the construction progress will be directly delayed. In order to avoid the impact of improper process arrangement on the construction progress, the general contractor needs to make preparations before construction, including analyzing the possible factors in the construction in advance and formulating a practical process arrangement plan. At the same time, the general contractor also needs to coordinate all disciplines and participating units to clearly explain the operation sequence and the convergence of work types, so as to avoid conflicts between disciplines and teams, which will lead to the delay of the overall project duration.

6. Conclusion

There are many risk factors affecting the progress of prefabricated construction projects. Different project participants face different risk factors, and there are complex interactions between these risk factors. Under the general contracting mode, the general contractor is fully responsible for the project construction, which faces great progress risk pressure. At present, the research on the project schedule risk of the general contractor is insufficient, resulting in the lack of guidance on the schedule risk control of the general contractor. From the perspective of the general contractor, based on grounded theory and interpretive structure model ism, this study defines the composition of project schedule risk and clearly understands these relationships:(1) Using the grounded theory method, 22 construction schedule risk factors are determined from the interview records of 25 experts, including 6 categories: technical scheme, project environment, personnel factors, component factors, equipment factors and construction management.(2) Based on these risks, 22 risk factors are divided into 7 levels by ISM, and a total of 60 progress risk transmission paths and four progress risk transmission chains including technical environment, environmental protection policy and EPC project experience

are obtained. (3) The characteristics of risk transmission are analyzed from various levels, and the direct and indirect factors affecting the project progress are divided. It is suggested that the general contractor should pay attention to the improvement of lower level risk factors to fundamentally improve the progress management ability, and do a good job in the control of upper level risk factors to avoid project progress delay. Finally, this study considers the risk factors of project schedule from the whole fabricated construction industry. Depending on the complexity of the prefabrication project, the risk factors listed in this study may not be fully involved. Future research will analyze the similarities and differences of different projects through some case studies.

7. Declarations

7.1. Author Contributions

X.S.: Conceptualization, Methodology, and Writing – Review & Editing; C.L.: Formal analysis, Data Curation and Writing - Original Draft; W.L.: Writing - Original Draft and Writing – Review & Editing; F.S.: Investigation; J.C.: Data Curation; K.M.: Writing – Review & Editing. All authors have read and agreed to the published version of the manuscript.

7.2. Data Availability Statement

The data presented in this study are available in article.

7.3. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

7.4. Conflicts of Interest

The authors declare no conflict of interest.

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