buildings

MDPI

Article

Stakeholder Behavior Risk Evaluation of Hydropower Projects Based on Social Network Analysis—A Case Study from a Project

Min An [1,2], Weidong Xiao [1,3], Hui An [1,3,*] and Jin Huang [1,2,*]

1 Hubei Key Laboratory of Construction and Management in Hydropower Engineering, China Three Gorges University, Yichang 443002, China
2 College of Economics & Management, China Three Gorges University, Yichang 443002, China
3 College of Hydraulic & Environmental Engineering, China Three Gorges University, Yichang 443002, China
* Correspondence: anhui@ctgu.edu.cn (H.A.); huangjin@ctgu.edu.cn (J.H.); Tel.: +86-155-7270-1791 (J.H.)

Abstract: Since construction involves many stakeholders and their behavioral risk interaction, which brings risks to the project construction, it is necessary to strengthen the research on the risk management of hydropower projects. This study comprehensively considers the characteristics of hydropower project construction and identifies relevant stakeholders to build and improve the stakeholder behavior risk evaluation index system. On this basis, the social network analysis method is used to build an evaluation model of stakeholders' behavioral risk transmission network, identify core factors and key relationships, analyze the path of behavioral risk transmission, take measures to cut off the transmission of core factors and key relationships, and test the effect of the risk network after control. The results show that: the evaluation model can effectively identify the core behavioral risk factors and key relationships in the construction process. Then, after taking targeted measures on the core behavioral risk factors and key relationships, hydropower projects are less affected by behavioral risk factors, and the risk transmission paths are reduced, which reduces the probability of behavioral risks arising from stakeholders and improves the behavioral governance efficiency of stakeholders. Applying this research model to the risk management of international hydropower projects can provide better guidance to the stakeholders and improve the accuracy and effectiveness of analyzing the behavioral risks of stakeholders in hydropower projects.

Keywords: hydropower projects; social network analysis; transmission path; stakeholder behavioral risk

check for updates

Citation: An, M.; Xiao, W.; An, H.; Huang, J. Stakeholder Behavior Risk Evaluation of Hydropower Projects Based on Social Network Analysis—A Case Study from a Project. *Buildings* **2022**, *12*, 2064. https://doi.org/10.3390/buildings12122064

Academic Editor: Alban Kuriqi

Received: 26 October 2022
Accepted: 22 November 2022
Published: 24 November 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

1. Introduction

The gradual increase in environmental pollution and global warming has made the energy transition urgent [1,2]. Hydropower is valued as a clean energy source, and countries have increased the construction of hydropower projects, hoping that this could bring multiple benefits to them [3]. At the same time, hydropower projects are characterized by long construction cycles, complex construction procedures, and difficult environmental proofs, resulting in delays, increased costs, substandard quality, and environmental pollution risks [4,5]. As the number and complexity of construction projects increase, the extent of the risk for stakeholders is increasing, and the risk management of hydropower projects faces serious challenges.

Risk management in hydropower projects mainly includes objective and subjective risks [6,7]. Objective risk means that it does not depend on human consciousness and transcends human subjective consciousness, and one can only change the risk and occurrence conditions in a limited time and space to reduce its probability of occurrence, such as: natural environmental risks, technological risks, etc. [6]. With the progress of science and technology and the refinement of the social division of labor, the probability of objective risk in hydropower projects is gradually reduced [8]. Meanwhile, subjective risks are behavioral risks caused by human factors that can be avoided or controlled by people themselves, which now receive more attention [7]. Specifically, stakeholders are the most active productivity factors throughout the engineering projects, and the complexity and uncertainty of their behavior may trigger the occurrence of risk events [9,10]. However, most of the current studies control the occurrence of objective risk events, analyze the probability of the occurrence of risk events and the resulting losses [11], and have not yet conducted systematic research on stakeholder behavioral risks. Therefore, how to identify the behavioral risk factors and key relationships of hydropower project stakeholders is a worthy research problem for hydropower project risk management.

Stakeholders are not only the sources of behavioral risk but also the disseminators and receivers of behavioral risk [12]. The cooperative exchange of many stakeholders provides the path basis for behavioral risk transmission, which makes risk transmission complex and dependent [13]. In turn, the construction of hydropower projects brings together many stakeholders and their behavioral risk into a tight network structure, generating behavioral risk relationships and forming a complex behavioral risk transmission path. Therefore, the use of the social network analysis method in this study is conducive to restoring the process of influence between behavioral risks, analyzing the degree of influence between behavioral risks, and clarifying the transmission path between behavioral risks, which is of great significance for improving the efficiency of stakeholder behavior governance.

2. Literature Review

2.1. Project Risk Management

The risk management framework for engineering projects mainly includes risk identification, analysis, assessment, and control [14]. Risk evaluation studies on internal factors such as the construction schedule, cost, and quality of hydropower projects are currently conducted through this framework [15–17]. At the same time, the social environment external risk control is also one of the elements of successful hydropower project construction, including social risks and environmental risks, such as policy changes, natural disasters, etc. [18–20]. However, only considering the evaluation of risks such as the schedule, cost, quality, and social environment is not comprehensive enough, and scholars continue to explore the research on the risk management of hydropower projects in terms of organizational structure and construction safety [21,22]. From the above analysis, the existing hydropower project risk management mainly focuses on objective risk studies such as the schedule, cost, quality, and safety, neglecting the control and prevention of subjective risks caused by the behavioral risk factors of hydropower project stakeholders, etc.

Thevendran and Mawdesley [23] identify the human risk factor as the most influential construction risk and emphasize its necessity in project risk management. On this basis, some scholars have qualitatively analyzed the importance of human risk factors from internal stakeholders such as owners, contractors, and designers [24–26]. Despite the awareness of the importance and necessity of stakeholders' behavioral risk factors, it is far less popular and in-depth than the traditional risk factor research and lacks systematic behavioral risk factor identification and evaluation. Some scholars have even constructed their behavioral risk factor index systems from internal stakeholders such as owners, contractors, and designers to quantitatively analyze the impact of behavioral risk on project construction [27]. However, the behavioral risks of external stakeholders, such as migrants, governments, and environmental departments, are not considered, resulting in an imperfect behavioral risk indicator system. The analysis of the relationship between the behavioral risks of stakeholders is insufficient. Meanwhile, due to the mutual influence of behaviors among stakeholders, some scholars further study the synergy and partnership among stakeholders in project construction [28–31]. However, behavioral risk relationships are not integrated into the risk network to analyze the impact of overall relationships on the construction of engineering projects.

2.2. Social Network Analysis (SNA)

The method of social network analysis originated from sociology. With “people” as the core, it analyzes the subjective initiative of individuals in the network and the constraints of the social structure on people in the network [32]. In addition to the field of sociology, psychology, medicine, and finance also widely apply social network analysis to study the interaction between individual rational choices and collective constraints [33–35].

In recent years, many scholars [36] have introduced SNA into the field of engineering to study the relationship between individuals and collectives related to engineering projects. This method is also increasingly widely used in the field of engineering project management. Lin [37] used SNA to identify the core stakeholders of hydropower projects but did not comprehensively consider the influence relationship of risk factors among the stakeholders. On this basis, Herrera, et al. [38] used SNA to analyze the interaction influence relationship between designer groups and their members in a multidimensional manner but lacked the analysis of the influence of behavioral relationships between other stakeholders. Tang, et al. [39] used SNA to explore the cost–risk relationships of stakeholders in project construction to obtain key cost–risk relationships. Lu, et al. [40] used SNA to study the organizational structure risk relationship of stakeholders in construction projects and found that streamlining the organizational structure and improving the efficiency of personnel communication can reduce risk generation. In summary, the current use of SNA studies engineering project risk relationships from core stakeholders, stakeholder cost risks, and organizational structure risks, but it does not take measures to prevent the impact of the stakeholder behavior risk relationships generated, which makes it difficult to achieve the ultimate project risk management goals. Therefore, based on the analysis of risk relationships related to stakeholders, some scholars use SNA to combine stakeholder management with risk management, propose preventive measures and mechanisms to control the risk relationships generated, and provide a reference for preventing various types of risks [41,42]. However, this study only considers the advantages and disadvantages of risk relationships and takes measures to prevent the impact of risk. The risk relationship transmission path of stakeholders has not been studied, and there are problems such as the unclear influence process and the unclear degree of influence when describing the behavior risk relationship of stakeholders. Therefore, this study uses the SNA method to build a behavioral risk transmission network for stakeholders of hydropower projects, analyze the behavioral risks among stakeholders of the project, and determine the core behavioral risk factors and key relationships. Starting from the risk transmission path, take corresponding measures to cut off risk factors and relationship transmission and prevent behavior risk events.

In summary, different scholars have studied engineering project risk management in terms of objectivity, subjective behavioral risk, and the use of social network analysis. However, there are still two shortcomings: (1) In the current research on project risk management, the evaluation index system of stakeholders’ behavioral risks is not improved. (2) In the existing research on engineering risk management using SNA, the analysis of the behavioral risk association relationship is lacking. Stakeholders are not embedded in the network structure to analyze the degree of influence between behavioral risks and the transmission paths.

Therefore, for the shortcomings of the existing studies, this study will be improved in the following aspects: (1) From the construction process of hydropower projects involving many stakeholders and frequent risky accidents. The stakeholders of hydropower projects and their behavioral risk factors are screened and identified using the literature, interviews, and questionnaires to improve the behavioral risk evaluation index system. (2) Use social network analysis to consider the relationship between specific behavioral risk factors, establish a behavioral risk transmission network, explain the key relationships and diffusion paths between risks, and take corresponding measures to prevent the occurrence of risks. The innovations are: (1) Building and improving the project construction stakeholders’ behavior risk evaluation index system; (2) Using the social network analysis method to identify core factors and key relationships, analyze behavioral risk transmission paths, and take measures to cut off the propagation of core factors and key relationships. This study provides a reference for the related research of hydropower project risk management and promotes the sustainable development of hydropower project construction.

3. Research Approaches

In this study, the social network analysis method is applied to the project risk management theory, and an evaluation model of stakeholder behavior risk management for hydropower projects is proposed. This evaluation model uses social network analysis tools to visualize the behavioral risk assessment of stakeholders in hydropower projects and to quantitatively analyze the behavioral risk relationship and impact degree between individual networks and the overall network. At the same time, after taking measures to control the core behavioral risk factors and key relationships, social network analysis tools are used to test the behavioral risk response of stakeholders, and visual and quantitative analysis is conducted on the behavioral risk after testing. The combination of the social network analysis method and project risk management theory is conducive to the combination of the qualitative and quantitative analysis of project risk management to better realize risk identification, assessment, and response evaluation. Moreover, the behavioral risk relationship of stakeholders is visualized, which is conducive to the project risk management to clarify the behavioral risk relationship of stakeholders and the specific path of risk transmission.

The specific steps are as follows: First, identify and determine stakeholders and their behavioral risks by using a literature review, expert consultation, and other methods, and list the relevant stakeholders and behavioral risk factors. Second, the behavioral risk relationship of stakeholders is evaluated by a questionnaire and other methods to determine the behavioral risk relationship and transmission path of stakeholders. Third, the social network analysis method is used to evaluate the behavioral risk relationship and transmission path visually and quantitatively and determine the core behavioral risk factors and key behavioral relationships. Finally, targeted measures are taken to control the relationship between core behavioral risk factors and key behaviors, and social network analysis methods are used to respond to the controlled behavioral risk network, as shown in Figure 1.

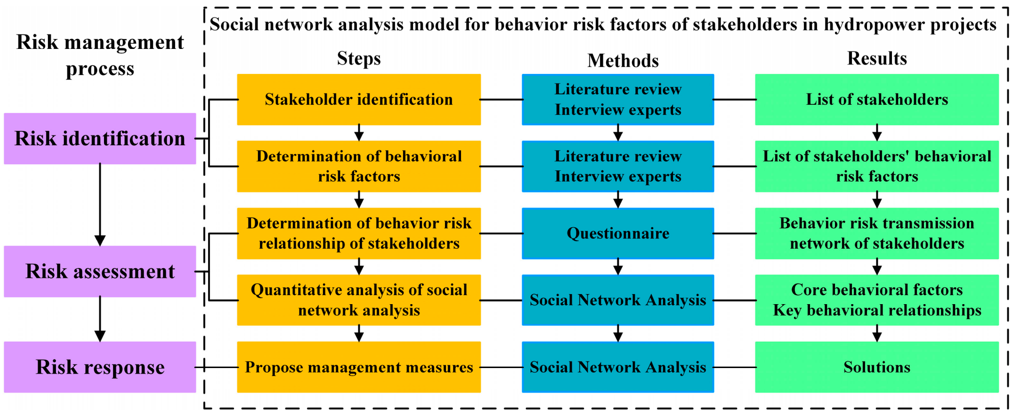

Figure 1. Research model framework.

3.1. Indicators System Construction

This study constructs an evaluation index system for stakeholders and their behavioral risk factors. The steps are as follows: First, preliminarily identify stakeholders and their behavioral risk factors through literature combing. Second, experts with rich engineering project management practice, scientific research experience, and research work in hydropower are invited to participate in the identification and classification of stakeholders and behavioral risk factors, and the information of experts is shown in Table 1.

Finally, the preliminary identification results are corrected and optimized by comprehensive expert suggestions to determine the final stakeholders and their behavioral risk factors evaluation index.

Table 1. Experts Information.

Expert	Work Unit	Position	Work Experience (Years)	Expert	Work Unit	Position	Work Experience (Years)
1	College	Professor	10	6	Supervisor	Director representative	8
2	Owners	Department manager	7	7	Designer	Engineer	7
3	Designer	Engineer	6	8	Contractors	Project manager	8
4	College	Associate professor	8	9	College	Lecturer	6
5	Contractors	Project manager	6	10	Owners	Department manager	8

Stakeholders are broadly defined as individuals, groups, or organizations that may be affected by the decisions, activities, or outcomes of a project. The purpose is to avoid the arbitrary or deliberate exclusion of certain stakeholders. Select the literature on the stakeholder risk assessment of large-scale engineering projects and hydropower projects. The stakeholders appearing in each work of literature are summarized and counted, and 14 stakeholders are initially identified, as shown in Table 2.

Table 2. Initially Identified Stakeholders.

Literature	Stakeholders													
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14
Lee, et al. [43]	√	√	√	—	√	—	—	—	√	—	—	—	√	—
Xia, et al. [44]	√	√	√	√	√	√	—	—	—	√	√	—	√	—
Zhang, et al. [45]	√	√	√	√	—	—	—	—	—	—	—	—	—	—
Ding, et al. [46]	√	√	—	—	√	—	—	—	√	—	—	√	—	√
Mok, et al. [47]	√	√	√	√	√	√	—	—	—	—	—	—	—	—
Sadkowska [48]	√	—	√	√	√	√	√	—	—	—	—	—	—	—
Amadi, et al. [49]	√	√	√	—	—	√	—	—	—	—	√	—	√	√
Daniel, et al. [50]	√	√	√	√	—	—	—	√	—	√	—	—	—	—
Luo, et al. [51]	√	√	√	√	—	√	√	—	—	—	—	—	—	—
Bahadorestani, et al. [52]	√	√	—	√	√	√	√	√	—	√	—	—	—	—
He, et al. [53]	√	√	—	√	√	—	—	—	—	—	—	—	√	—
Nguyen, et al. [54]	√	√	√	—	—	—	√	—	—	—	—	—	—	—
Jia, et al. [55]	√	√	—	√	√	—	—	—	—	—	—	—	—	—
Wen and Qiang [56]	√	√	—	√	√	—	√	—	—	—	√	—	—	—

S1–S14: Owners; Contractors; Subcontractor; Designer; Government; Supplier; Supervisor; Environmental Departments; Media; Financial Institution; Research Institutions; Operator; Natives; Consulting Company.

To identify the final stakeholders associated with the project construction of the hydropower project, experts were invited to conduct interviews to clearly explain the definition of each stakeholder in the initial identification list. The experts were also consulted on the following issues: whether the names and definitions of the initially identified stakeholders (*Si*) were appropriate and whether they needed to be modified; what important roles the above stakeholders (*Si*) usually played in a typical project; whether stakeholders (*Si*) play a role in the construction of the project and whether their actions will have an impact on the construction of the project; whether initially identified stakeholders (*Si*) need to be removed or added, and for what reasons. Based on the results of the above expert interviews, the stakeholders of the hydropower project construction were modified and improved, as shown in Figure 2. The stakeholders in the construction of hydropower projects are identified as the owners (the responsible body for hydropower project construction, which is responsible for project planning, financing, construction implementation, etc.), the designer (responsible for hydropower project design work), the contractors (responsible for hydropower project construction, transportation, labor, and other works), the supervisor (responsible for hydropower project supervision tasks), the material and equipment suppliers (responsible for providing hydropower project materials and equipment), the government (hydropower project location of government agencies), the immigrant (the masses affected by the construction of hydropower projects and involuntary relocation), and the environmental departments (in accordance with the relevant laws to implement the supervision and management of environmental protection law enforcement departments), respectively, with S1, S2, S3, S4, S5, S6, S7, and S8.

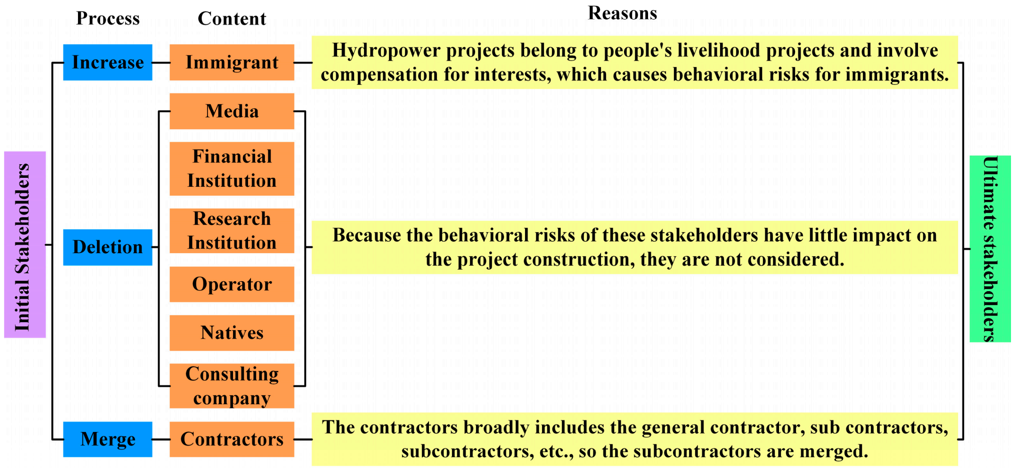

Figure 2. Stakeholder Identification Process.

Risk consists of two factors: the uncertainty of the occurrence of the event and the hazards arising after the occurrence. Therefore, hydropower project stakeholder behavioral risk is defined as the factors that are related to the subjective behavior of stakeholders in the construction of hydropower projects and have an uncertain impact on the successful achievement of project objectives. Identifying behavioral risk factors is not only a key step in establishing a behavioral risk evaluation model but is also a basis for effective risk management. Therefore, the literature studying the risk factors and impact categories of hydropower projects was selected, the behavioral risk factors appearing in each work of literature were summarized and counted, and 22 behavioral risk factors were initially identified, as shown in Table 3.

Table 3. Initially Identified Behavioral Risk Factors.

Factors	Literature							
	Yang and Zou [57]	Wu, et al. [58]	Yang, et al. [13]	Wang, et al. [27]	Xiang, et al. [26]	Xia, et al. [59]	Darvishi, et al. [60]	Barghi and Shadrokh Sikari [61]
R1	√	√	—	√	—	—	—	—
R2	—	√	—	—	√	—	—	—
R3	—	—	√	—	—	—	—	√
R4	√	—	—	√	—	√	—	√
R5	—	√	—	√	—	—	—	—
R6	—	—	√	—	√	—	—	—
R7	√	√	—	—	—	√	—	√
R8	—	—	√	√	√	—	—	—
R9	—	—	√	—	—	—	—	—
R10	—	—	—	√	√	—	—	—
R11	√	—	—	√	—	—	√	—
R12	√	—	—	—	—	—	√	—
R13	—	—	—	√	—	—	√	—
R14	—	—	—	—	—	√	—	√
R15	√	√	—	—	—	—	—	—
R16	√	—	—	—	—	√	—	√
R17	—	√	—	—	—	√	—	√
R18	—	—	√	—	—	√	—	√
R19	—	—	√	—	—	√	—	√
R20	—	—	—	√	—	—	—	—
R21	—	—	√	—	—	√	—	√
R22	—	—	√	—	—	√	√	—

R1–R22: Difficulty in paying funds; Proactive change request; Design changes; Project not delivered on schedule; The design does not consider ecological protection; Construction costs exceeded budget; Construction quality not up to standard; Inappropriate construction safety measures; Lack of timely implementation monitoring; Irregular supervision process; Substandard quality; Lack of timely supply of material and equipment; Supply price adjustment; Policy changes and adjustments; Decision approval and delay; Call off construction; Poor coordination skills; Create public opinion; Destruction of cultural customs; Poor quality of life; Disrupting construction sites; Not strictly enforcing environmental standards.

To finally determine the behavioral risk factors of stakeholders in hydropower project construction, experts were invited to conduct interviews to screen and classify the behavioral risk factors of stakeholders. The experts were also consulted on the following issues: whether the behavioral risk factors (Rj) are subjective behaviors of stakeholders (Si); whether the behavioral risk factors (Rj) of stakeholders (Si) themselves are independent; whether the behavioral risk factors (Rj) among stakeholders (Si) have a direct impact; whether the behavioral risk factors (Rj) are applicable to the project construction. Based on the results of the above expert interviews, the risk factors for stakeholder behavior in the construction process of hydropower projects are modified and refined, as shown in Figure 3.

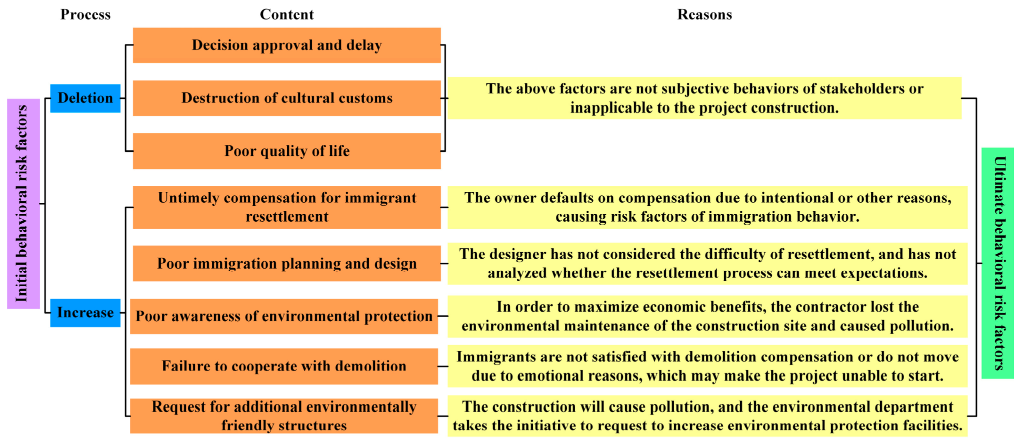

Figure 3. Behavioral Risk Factor Identification Process.

In summary, a total of eight stakeholders and their corresponding 24 behavioral risk factors were identified for the construction of hydropower projects, as shown in Table 4.

Table 4. Identification and classification of behavioral risk factors for hydropower projects.

Stakeholders	Behavior Risk Number	Behavioral Risk Factors	Behavioral Risk Factors Description
Owners (S1)	R1	Difficulty in paying funds	Owners are difficult to finance, lack of fund preparation, and lack of willingness to pay.
	R2	Proactive change request	May directly lead to a chain reaction in the construction process and increase the direct and indirect cost of the project and quality risk.
	R3	Untimely compensation for immigrant	Improper immigrants easily cause public resentment and anger, and there are problems such as insufficient investment in immigrants.
Designer (S2)	R4	Design Changes	Incomplete design drawings and lack of communication with the construction party and construction unit resulted in changes.
	R5	Poor immigration planning and design	The difficulty of immigrants has not been considered, as well as whether it can meet the expectation of immigration, resulting in backward work and other problems.
	R6	The design does not consider ecological protection	Designers lack environmental awareness or ignore environmental issues to save costs.
Contractors (S3)	R7	Project not delivered on schedule	Contractors have their own uncertain factors, as well as the actual construction and the planned progress of deviation.
	R8	Construction costs exceeded budget	The actual construction cost exceeds the planned cost due to mismanagement, malicious low bids, price fluctuation, and other reasons.
	R9	Construction quality not up to standard	Lax supervision of construction materials and shoddy phenomena occur, easily causing engineering quality and safety accidents.
	R10	Inappropriate construction safety measures	Without scientific safety production, standardization, and standardized management of the site, there are safety risks on the site.
	R11	Poor awareness of environmental protection	The environment of the construction site is not managed, resulting in air, water, and ecological pollution to the surrounding environment.
Supervisor (S4)	R12	Lack of timely implementation monitoring	Delayed supervision of the site and failure to rectify hidden dangers in time lead to project risks.
	R13	Irregular supervision process	The supervisor and the contractor conspire to pursue their own interests and lower the project quality standard.

Table 4. *Cont.*

Stakeholders	Behavior Risk Number	Behavioral Risk Factors	Behavioral Risk Factors Description
Material & Equipment Suppliers (S5)	R14	Substandard quality	Use sub-standard materials and equipment instead of quality standard equipment to provide maximum benefit to the contractor.
	R15	Lack of timely supply of material and equipment	Material shortage, suppliers do not perform their own responsibilities, and material supply is not timely.
	R16	Supply price adjustment	As market prices rise, suppliers take the initiative to increase the agreed supply price, resulting in disputes with contractors.
Government (S6)	R17	Policy changes and adjustments	Changes in national laws and regulations and other relevant documents cause local governments to issue the latest policies for governance.
	R18	Call off construction	As the project is not up to standard and is in violation of laws and regulations, the government directly stops the construction rectification.
	R19	Poor coordination skills	Due to the lack of capacity of government personnel, the coordination of various parties cannot be well completed.
Immigrant (S7)	R20	Create public opinion	Dissatisfied with the immigration plan, the media and other means are used to protect their rights and create relevant public opinion.
	R21	Disrupting construction sites	Dissatisfied with the immigration scheme, some immigrants may take relatively radical actions to disrupt the construction site.
	R22	Not cooperating with demolition	Not being satisfied with the compensation or emotional reasons for not moving may prevent the project from starting.
Environmental Departments (S8)	R23	Not strictly enforcing environmental standards	Some law enforcement officials conspire with contractors to pursue their own interests and lower environmental enforcement standards.
	R24	Request for additional environmentally friendly structures	The construction process lacks the relevant environmental protection facilities; the environmental departments require that it be increased.

3.2. SNA Model Construction

3.2.1. Overall Network Structure

1. Network density

Network density is a measure of node compactness in a risk network model. The higher the network density, the closer the connection between nodes, and the overall network structure presents a stable state. The calculation of bivariate directed network density is shown in Equation (1),the range of D is (0,1) [62].

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

where L is the number of relationships between risk factors influencing each other; and n is the number of behavioral risk factors of stakeholders.

2. Block Model

The block model describes the relationship between actors, represents the relationship between the positions of each actor, reflects the influence relationship between each block, and makes the influence relationship of the whole behavioral risk network clearer. The behavioral risk factors of stakeholders in hydropower projects are divided into set discrete subgroups according to certain criteria, which are called "blocks", and each block is a subgroup of the whole risk network. Main steps of block model analysis: first, the behavioral risk factors of stakeholders in hydropower projects are classified by the *CONCOR* method (the iterative correlation convergence method, which iterates the correlation coefficients between each row or column in the matrix and eventually produces a correlation coefficient matrix consisting of only 1 and -1 to achieve a partitioning of the corresponding individual actors, thus simplifying the data), and each class is taken as a block to obtain the block matrix and density matrix. Second, the value of each block is determined according to certain criteria, i.e., 1-block or 0-block. The criteria used for relationships of different natures are different, and the most common is the α- Density index. Compare the density matrix with the density of the whole network. If the density is greater than the density of the whole network, take "1" in the image matrix and "0" in the image matrix to obtain the image matrix. Finally, core blocks are identified by obtaining the block matrix, density matrix, and image matrix and analyzing the location characteristics of blocks in the whole network [62].

3. Clustering coefficient

The clustering coefficient reflects the closeness of the whole network. A larger value of the clustering coefficient indicates that the behavioral risk factors are more closely linked, the hidden risk is greater, and the likelihood of project failure is greater. Equation (2) is the calculation process [62].

$$C = \frac{1}{n}\sum_{i=1}^{n}\frac{E_i}{k_i(k_i-1)} \tag{2}$$

where n is the number of behavioral risk factors of stakeholders; E_i represents the total number of relationships between stakeholder i behavioral risk factors; k_i denotes the number of stakeholder i-related behavioral risk factors; and $k_i(k_i-1)$ denotes the total number of stakeholders point i behavioral risk factors.

4. Intermediate central potential

The intermediate centrality potential is to measure the gap between the point with the highest centrality in the network and other points. It tests the ability of a specific point to control the entire network. The calculation is shown in Equation (3) [42].

$$C_B = \frac{\sum_{i=1}^{n}(C_{\max}-C_i)}{n^3-4n^2+5n-2} \tag{3}$$

where n is the number of behavioral risk factors of stakeholders; C_i is the intermediate centrality of the stakeholder i; and $C_{\max}$ is the maximum of all C_i.

5. Accessibility

Reachability refers to a kind of data transferability closed circle that is used to judge the degree of network connectivity; the higher the value indicates that its risk factors transfer more smoothly. The calculation is shown in Equations (4) and (5) [62].

$$(A+I) \neq (A+I)^2 \neq, \cdots, (A+I)^r = (A+I)^{r+1} = M, r < n-1 \tag{4}$$

$$C = 1 - \left(\frac{V}{N(N-1)/2}\right) \tag{5}$$

where M represents the reachable matrix; C represents the network reachable; A represents the adjacency matrix, I represents the identity matrix; V represents the number of unreachable point pairs in the network; and N represents the network scale.

3.2.2. Individual Network Structure

1. Intermediary

An intermediary is defined as a person in the middle, regardless of whether he receives a reward. Its function is to group the whole network node and to study how different groups transmit through risk factors. To better clarify the definition of "intermediary", further understand how to transfer the risk factors of stakeholder behavior. The specific description is as follows: If the risk relationship transmission path is A→B→C, B is the intermediary. Specific roles are distributed according to the positions of the three, and circles of the same color represent the same group. If all three are in the same group, B is the coordinator; if A and C are in the same group, B is not in the group, and B is the consultant; if B and C are in the same group and A is not in the group, then B is the gatekeeper; if A and

B are in the same group and C is not in the group, then B is the representative; if A, B, and C are in different groups, B is the liaison [62], which is described in Figure 4. The results of this study selected 35% of the 24 behavioral risk factors as important risk factors [13].

2. Point Median Center Degree

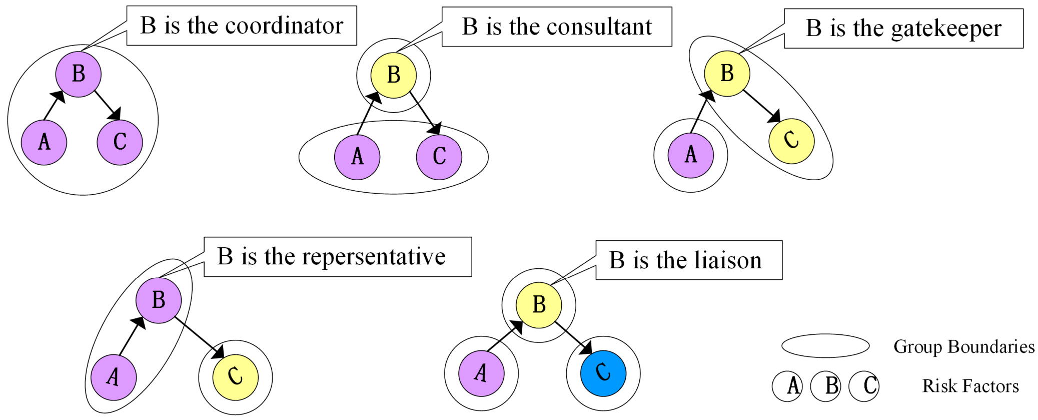

Figure 4. Description of the five types of intermediaries.

The intermediate centrality of a point refers to the fact that a point is in a critical position in the network if it is on multiple interaction paths. The larger the value of a point, the stronger its ability to control the conduction of other nodes and the more critical the network position. The calculation is shown in Equations (6) and (7) [63]. The results of this study selected 35% of the 24 behavioral risk factors as important risk factors [13].

$$C_i = \sum_j^n \sum_k^n b_{jk}(i), j \neq k \neq i, and, j < k \tag{6}$$

$$b_{jk}(i) = g_{jk}(i)/g_{jk} \tag{7}$$

where g_{jk} and g_{jk} *(i)* denote the number of paths and paths between stakeholders *j* and *k*, respectively; and b_{jk} *(i)* denotes the ability to interact between stakeholders *j* and *k*.

3. Line Center Degree

The line center degree is the ability to transfer and control risk factors in the network. Measure the control degree of a line on information. The greater the value, the stronger the risk control transmission ability. It is calculated in Equation (8) [62]. In this study, 15% of the line intermediate centrality values higher than 0 risk relations were considered as critical relations [13].

$$C_{p \to q} = \sum_j^n \sum_k^n b_{jk}(p \to q), j \neq k \neq p \neq q, j < k \tag{8}$$

where b_{jk} *(p→q)* represents the ability of the control stakeholders *j* and *k* of relation *p→q* to communicate; and *n* denotes the total number of behavioral risk factors of stakeholders.

4. Empirical Analysis

4.1. Research Examples

This study takes the Chongqing JL Hydropower Project as the empirical object. This project is in Qi Jiang District, Chongqing, and involves many immigrants. It is a comprehensive large-scale power station hub project focusing on power generation and considering flood control, water supply, and shipping. The reservoir has a total storage capacity of 5.163 billion cubic meters, a regulated storage capacity of 900 million cubic meters, and a backwater length of 156.6 km.

This hydropower project has complex construction procedures, many risk factors, and many stakeholders with complex relationships, which are in line with the characteristics of most hydropower projects. It can provide a basis for verifying the rationality and feasibility of the stakeholder behavior risk transfer network evaluation model for hydropower project construction [64]. At the same time, the project is in the early decision-making stage, so it is necessary to carry out risk analysis and prevention in advance for its construction process in order to reduce the economic losses of various stakeholders and provide a reference for the construction of other hydropower projects [65].

4.2. Questionnaire Design and Statistical Analysis

The questionnaire content is mainly considered according to the behavior risk evaluation index system of stakeholders of hydropower projects. Proceeding from the self-interest and subjective behavior of various stakeholders, it is mainly based on the construction period, cost, quality, production capacity, and market. The project construction stakeholder behavioral risk factor inter-impact questionnaire was applied to the Chongqing *JL* hydropower project. The content of the questionnaire only requires the respondents to fill in the corresponding matrix and identify the possible influence relationship, which greatly reduces the number of judgments and improves the efficiency and quality of the questionnaire. The questionnaire involves a total of eight stakeholder corresponding behavioral risk factor influence matrices [66], and the instructions and requirements for filling them out are shown in Appendix A. (Due to the large number of questionnaires, this paper only takes the owners as an example, and the questionnaires of other stakeholders are similar.)

The questionnaire data are the basis for constructing the risk network of hydropower projects. Therefore, before the construction of the major *JL* hydropower project in Chongqing, 269 questionnaires were sent out in the form of email and paper, 249 were returned, and 240 were valid. The valid response rate was 89.2%. The background information of participants was shown in Table 5. From Table 5, we can see that: (1) The source of participant units includes stakeholders selected from the study, in which there are more sample data of owners, designers, contractors, and governments, while there are fewer sample data of supervisors, material and equipment suppliers, immigrants, and environmental departments. (2) A higher percentage of participants had a higher education and a longer working life. Among them, 93.72% have a bachelor's degree or above and 77.55% have a working life of more than 5 years. (3) A total of 88.72% of participants have experience in hydropower project construction, which indicates that most participants have rich experience in hydropower project construction.

Table 5. Background information for participants.

Unit Source	Owners 14.27%	Designer 15.73%	Contractors 28.64%	Supervisor 11.36%	Suppliers 10.56%	Government 12.44%	Immigrants 5.28%	Environmental Departments 1.72%
Education	Junior College 5.59%	Undergraduate 64.41%	Master 26.21%	Doctor 3.1%	Other 0.69%			
Work life	≤5 years 22.45%	6–10 years 40.5%	11–15 years 27.55%	16–20 years 8.45%	≥20 years 1.05%			
Participation in hydropower project construction	0 11.28%	1 38.72%	2 25.88%	3 13.97%	≥4 10.15%			

First, construct the "Filler–Fill Results" matrix through 240 valid questionnaires. Second, the consistency analysis of the "filler–finisher" matrix showed that the ratio of the first characteristic value to the second characteristic value was 3.046, which was greater than the general principal value of 3 [67]. This proved that the collected data had a single answer mode, and the questionnaire data met the requirements of social network analysis. Finally, because the relationship in the questionnaire belongs to the single answer mode, the questionnaire results are sorted according to the principle of the minority obeying the majority, and the adjacency binary directed matrix of the influence relationship between the behavioral risk factors of hydropower project stakeholders is constructed. "1" means that the behavioral risk factors of the row will have an impact on the behavioral risk of the column, and vice versa for "0". The original data used for analysis are shown in Appendix B.

4.3. Risk Network Visualization

A visualization of the risk network for stakeholder behavior in hydropower projects is shown in Figure 5. Among them, each node *SiRj* indicates *j* behavioral risk factors of *i* stakeholders, with a total of 24 nodes. The node color represents the stakeholder group. The directed arrow line between each node indicates the connection between the behavioral risk factors of each stakeholder, and the arrow represents the direction of the relationship between the nodes.

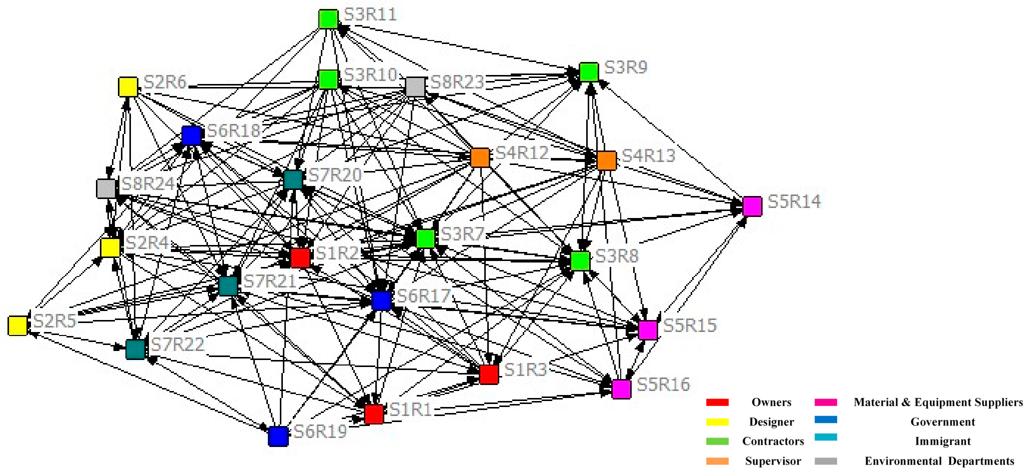

Figure 5. Behavioral risk network visualization for hydropower projects.

From Figure 5, the overall network is more densely connected, which indicates that the behavioral risk factors are interdependent and highly connected, reflecting the complexity of risk transmission in the construction process of the *JL* hydropower project.

There are S1R2 (Owners–Proactive change request), S3R7 (Contractors–Project not delivered on schedule), S6R17 (Government–Policy changes and adjustments), and S7R20 (Immigrant–Create public opinion) behavioral risk factors located in the center of the network, which may have a greater impact on the overall construction process.

On the contrary, behavioral risk factors located at the edges of the network, such as S2R5 (Designer–Poor immigration planning and design), S6R19 (Government–Poor coordination skills), S5R14 (Material & Equipment Suppliers–Substandard quality), S3R9 (Contractors–Construction quality not up to standard), etc., may have a smaller impact.

4.4. Risk Network Metrics Analysis

The analysis of risk network indicators focuses on the overall network and individual networks [63]. The overall network uses a block model to delineate the core risk subgroups in the network. Individual networks are analyzed in terms of intermediary analysis as well as intermediate centrality to identify the actors that are at the core of the network. Therefore, this study analyzes the overall network and individual network for the behavioral risk network of stakeholders in hydropower projects to identify the key behavioral risk factors and key relationships.

4.4.1. Overall Network Analysis

First, the network density in the behavioral risk network of hydropower projects is analyzed, and the value is 0.3351, which is between (0,1). This shows that the relationship between behavioral risks in the network is complex. Secondly, the adjacent binary directed matrix is iterated by the *CONCOR* method and finally divided into eight "blocks". Finally, the density matrix and the "like" matrix [68] are used to determine whether the "block" is in the core position of the network (both receiving and emitting relations; internal relations are close), and the core blocks are block 1 (S1R1 and S3R8), block 2 (S3R7, S3R9 and S5R15), block 3 (S1R2, S2R4, and S8R24), block 4 (S6R17, S6R18, S7R20, and S7R21), block 6 (S5R16 and S6R19), and block 8 (S4R12, S4R13, and S8R23).

4.4.2. Individual Network Analysis

First, the intermediary analysis is conducted on the behavioral risk network of hydropower projects, and the total number of five types of intermediaries accounted for 59.4% of all risk factors (540 in total). The behavioral risk results of the top eight who assumed the role of intermediaries are taken as important risk factors. Second, the intermediate centrality of their points is analyzed to obtain the intermediate centrality of each point, and the results of the top eight stakeholder behavioral risk factors are taken as important risk factors. Finally, the key risk factors for individual network analysis are obtained by taking the union of the important risk factors of both the intermediary and the point intermediate center degree as S1R1 (Owners–Difficulty in paying funds), S2R4 (Designer–Design Changes), S3R7 (Contractors–Project not delivered on schedule), S3R8 (Contractors–Construction costs exceeded budget), S4R12 (Supervisor–Lack of timely implementation monitoring), S6R17 (Government–Policy changes and adjustments), S6R18 (Government–Call off construction), S7R20 (Immigrant–Create public opinion), and S7R21 (Immigrant–Disrupting construction sites).

4.4.3. Key Relationships Analysis

The risk network was analyzed for line middle centrality, and it was found that there existed 185 groups of risk relationships with a line middle centrality greater than 0. However, the smaller the value, the smaller the impact between behavioral risk factors. Therefore, only the top 30 relationships were selected as key relationships, Table 6 shows the key relationships.

Table 6. Identification of key relationships in the top 30 risk network rankings.

Ranking	Risk Factors	Ranking	Risk Factors	Ranking	Risk Factors
1	S3R9→S6R18	11	S5R15→S6R17	21	S7R21→S6R18
2	S7R22→S6R19	12	S6R17→S6R18	22	S3R8→S3R9
3	S2R4→S2R6	13	S3R7→S5R16	23	S7R22→S6R18
4	S4R12→S8R23	14	S1R1→S7R22	24	S8R24→S6R18
5	S4R12→S4R13	15	S7R20→S6R18	25	S3R8→S5R15
6	S4R12→S3R11	16	S1R2→S1R1	26	S6R17→S7R22
6	S4R12→S3R10	17	S2R5→S6R18	27	S1R1→S7R21
8	S6R18→S4R12	18	S3R8→S5R14	28	S3R8→S1R1
9	S2R4→S2R5	19	S1R1→S1R3	29	S3R9→S7R20
10	S3R7→S7R20	20	S3R7→S3R9	30	S5R14→S3R9

4.5. Risk Network Control and Inspection

4.5.1. Core Risk Identification and Control

The core risk factors obtained from the individual network analysis are in the core block of the overall network analysis. Then, it is the core risk of the behavioral risk transmission network of the hydropower project [69], and its identification process is shown in Figure 6.

The key behavioral risk factors derived from the individual network analysis: S1R1 (Owners–Difficulty in paying funds) and S3R8 (Contractors–Construction costs exceeded budget) belong to block 1, S3R7 (Contractors–Project not delivered on schedule) belongs to block 2, S2R4 (Designer–Design Changes) belongs to block 3, S6R17 (Government–Policy changes and adjustments), S6R18 (Government–Call off construction), S7R20 (Immigrant–Create public opinion), and S7R21 (Immigrant–Disrupting construction sites) belong to block 4, and S4R12 (Supervisor–Lack of timely implementation monitoring) belongs to block 8. Since the overall network analysis yields block 1, block 2, block 3, block 4, and block 8 as the core blocks, the behavioral risk factors of the above hydropower project stakeholders are all core risk factors.

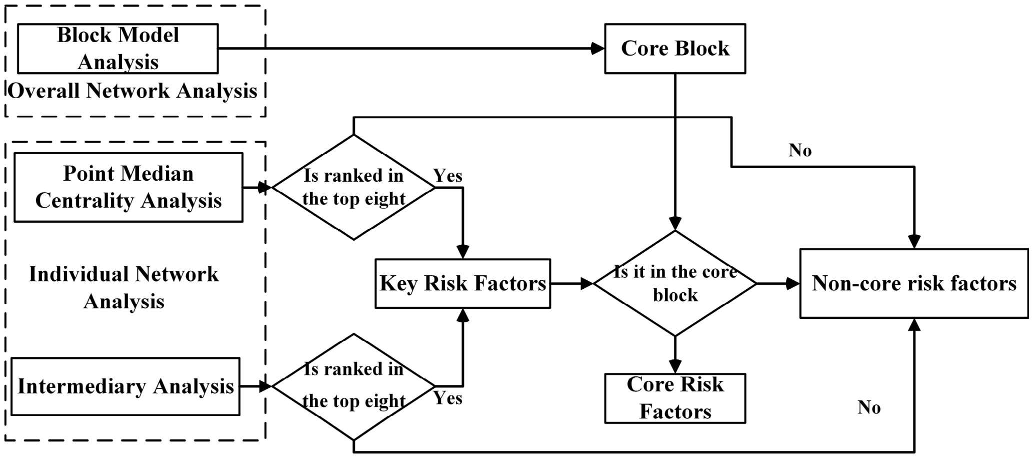

Figure 6. Core Risk Factor Identification Process.

Among the nine core behavioral risk factors, R1 (Difficulty in paying funds) belongs to the owners, R4 (Design Changes) belongs to the designer, R7 (Project not delivered on schedule) and R8 (Construction costs exceeded budget) belong to the contractors, R12 (Lack of timely implementation monitoring) belongs to the supervisor, R17 (Policy changes and adjustments) and R18 (Call off construction) belong to the government, and R20 (Create public opinion) and R21 (Disrupting construction sites) belong to the immigrant. The core behavioral risk factors involve six stakeholders who are all key participants in the construction of hydropower project projects, and project construction is also a key stage of the hydropower construction process. On the other hand, the nine key behavioral risk factors have nothing to do with material and equipment suppliers and environmental departments. It is related to the weak role of material and equipment suppliers in hydropower projects. Pay attention to the environmental problems in the construction of hydropower projects, enhance the environmental protection awareness of all stakeholders, and reduce the interest loss caused by the environment.

As can be seen from Table 6, except for the risk relationships ranked 2nd and 30th, all others are closely related to the nine core risk factors: R1, R4, R7, R8, R12, R17, R18, R20, and R21. Taking effective measures to control the key relationships is conducive to preventing some of the risks from being transmitted in the network [70–72]. Therefore, relevant measures are taken to control the relationship between core behavioral risk factors and key risks, as shown in Table 7.

Table 7. Risk response measures.

Type	Risk Factors	Stakeholders	Response
Core Factors	R1	Owners	(1) Establish sound rules and regulations for fund management and standardize the basic accounting work of construction projects. (2) Financial supervision, financial management, and fund control must be integrated into the project establishment and feasibility study stage. (3) Strengthen the management and control of project price settlement to prevent the occurrence of over-estimation, over-calculation, and false claims.
	R4	Designer	(1) Fully understand the requirements of the owners and timely communication to ensure the feasibility and accuracy of the program. (2) The quality department guides the design department to sort out the workflow to ensure that design changes are at a controllable level.
	R7,R8	Contractors	(1) Make a good construction organization and design plan, establish the target system of progress control, and clarify the personnel of progress control. (2) Conduct technical and economic analysis, determine the best construction plan, combine construction methods, and reduce material consumption costs. (3) Hold regular construction progress coordination meetings and adopt network planning techniques to implement the dynamic control of project progress.
	R12	Supervisor	(1) Supervisors should stick to their posts, conscientiously perform their supervisory duties, and not slacken their work.

Table 7. *Cont.*

Type	Risk Factors	Stakeholders	Response
			(2) Strictly control the quality of construction, check the quality of raw materials and intermediate products, and do a good job of side stations and acceptance work.
	R17,R18	Government	(1) Policy changes and adjustments should be in line with the actual situation and should not be changed casually. (2) Calling off construction cannot be a temporary notice; the site during the suspension of work needs to urge the contractor to rectify and implement the existing problems.
	R20,R21	Immigrant	(1) Actively express your demands with the relevant departments, exercise your rights legally and reasonably, and make efforts to cooperate with the relevant departments to do your duty. (2) Rational view of the project construction; shall not use force or false public opinion to defend rights; use the law to reasonably defend rights.
Key Relationships	Ranking	Key Relations	Response
	2	S7R22→S6R19	The government should actively coordinate with the immigrants, owners, and other parties involved in the project to solve the problem to achieve a balance of interests.
	30	S5R14→S3R9	Contractors should strictly control the quality of materials and equipment; the quality does not meet the standards to accept and use; prevent the construction quality that is not qualified.

4.5.2. Effectiveness Check

From the behavioral risk network of stakeholders in hydropower projects, after 9 core behavioral risk factors and 30 groups of key relationships were controlled, the risk factors were reduced from 24 to 15, and the risk relationships were reduced from 185 to 47. The risk network with the core behavioral risk factors and key relationships removed is shown in Figure 7. By visual comparison between Figures 5 and 7, the risk network becomes sparse, indicating that the risk factors in the network are less closely linked.

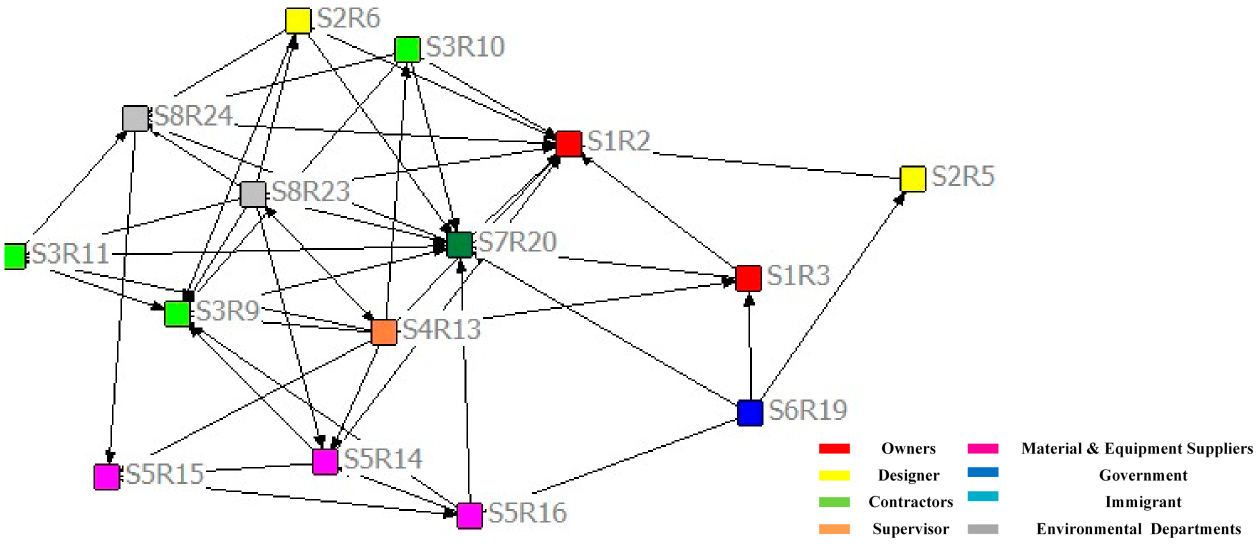

Figure 7. Stakeholder behavioral risk network after the elimination of core risks.

After the core behavioral risk factors and key relationships were controlled, the overall network effect was tested in terms of network density, clustering coefficient, intermediate central potential, and network accessibility, and the specific results were as follows.

(1) After the relationship between core risk factors and key risks is controlled, the overall network density is reduced from 0.3351 to 0.2238, which is a decrease of 33.2%. This shows that the close degree of risk relationship in the network is reduced, and the complexity of the network is effectively improved.

(2) The clustering coefficient is reduced from 0.387 to 0.241 after the core risk factors and key risk relationships are controlled, which is a 37.7% reduction. This shows that the diversity of risk transmission paths is reduced, which inhibits the frequency and activity of risk transmission.

(3) The intermediate central potential decreases from 0.1752 to 0.0904 after the core risk factors and key risk relationships are controlled, which is a decrease of 48.3%. This shows that the gap between risks is narrowed, and the control of risk factors over the whole network is weakened.

(4) The network accessibility value decreases from 0.1420 to 0.0444 after the core risk factors and key risk relationships are controlled, which is a decrease of 68.7%. This shows that the transmission path of multiple risk factors is cut off, and the connectivity of the network is effectively reduced.

5. Discussion

Under the framework of engineering project risk management, Wang, et al. [27] identify internal stakeholders such as designers and contractors and construct their corresponding system. Since internal stakeholders are not only limited to designers and contractors, there are also problems such as a lack of internal stakeholders and incomplete evaluation indexes. Based on this, this study adds internal stakeholders such as owners and supervisors and improves their corresponding behavioral risk evaluation indexes, such as untimely compensation for immigrants and unreasonable migration planning and design. Meanwhile, the existing studies focus less on the behavioral risks of external stakeholders such as governments and immigrants [37,40,42]. However, because the construction sites of hydropower projects are provided by the government, and the residents in the construction area need to actively cooperate with the project construction, external stakeholders are bound to be one of the conditions for the success of the project construction. Based on this, this study incorporates external stakeholder behavioral risk factors such as governments, immigrants, and environmental departments into the evaluation index system, such as: policy changes and adjustments and non-cooperation with demolition and relocation. The conclusion of this study shows that governments and immigrants can have an impact on the construction process of hydropower projects, and measures need to be taken to prevent this. Thus, the behavioral risk evaluation index system is constructed from the internal and external stakeholders involved in hydropower projects, which improves the behavioral risk indicators related to project construction and lays the foundation for a comprehensive analysis of the behavioral risk factors of hydropower project stakeholders.

Existing studies use engineering project risk management theory, which can effectively identify and quantify risk factors [22,28] but do not integrate multiple risk factors into risk networks to analyze their transmission paths. Therefore, this study combines social network analysis theory with engineering project risk management theory, integrates each behavioral risk factor into social network analysis, and constructs a stakeholder behavioral risk transmission network evaluation model. Meanwhile, some scholars also explain the importance and necessity of the behavioral risk of engineering project stakeholders and believe that behavioral risk has an influence on engineering project construction [19,25], without considering the influence relationship between behavioral risks. Based on this, this study uses the SNA method to analyze the impact of the overall relationship on the construction of hydropower projects and how to transfer the risk relationship. Targeted measures are taken to cut off the spread of core risks and key relationships. This highlights the ability to visualize risk network analysis among behavioral risk factors and enables hydropower project managers to clearly understand the core behavioral risk factors, key relationships, and risk transmission paths during the project construction.

This study proposes a conduction network model based on the SNA method to analyze risk relationships and control risks. Compared with traditional project risk analysis, this model breaks the limitations of the traditional project risk analysis framework and provides a risk management scheme for the construction phase of hydropower projects. It has the following practical risk management significance: (1) Dynamically understanding the impact between the behavioral risk factors of stakeholders in the construction process through the risk transmission path is conducive to taking measures to prevent the occurrence of risks and reduce the losses caused by risk events. (2) Provide project managers with new ideas for risk management, which should not only consider objective factors such as technology, investment, and safety management but also focus on the behavioral risks of stakeholders to promote the sustainable and healthy development of hydropower projects.

6. Conclusions

This study constructs and improves the stakeholder behavior risk evaluation system to study and evaluate the stakeholder behavior risk in its construction process. The stakeholder behavior risk network of hydropower projects is constructed through the SNA method, and the Chongqing *JL* hydropower project is selected as the research object to verify the rationality and feasibility of the evaluation model. To provide risk management experience for the construction of other hydropower projects in the future, the following conclusions are drawn from its study.

(1) The risk management of hydropower projects should not only pay attention to the behavioral risk factors of internal stakeholders but also pay more attention to the behavioral risk factors of external stakeholders.

(2) Attention should also be paid to the key relationships for the risk management of hydropower projects. According to the characteristics of the sending and receiving relationship of behavioral risk factors, specific countermeasures are proposed to block the transmission of core behavioral risks and cut off the transmission of key risk relationships.

(3) The methodology we put forward in this manuscript was an effective way to reduce the risks of hydropower projects management.

In this study, only the presence or absence of influence relationships between risk factors are considered when constructing the behavioral risk network of stakeholders in hydropower projects. However, there are strong and weak influence relationships between risk factors, and risk factors are induced only when the influence level exceeds a certain value. Therefore, this is the shortcoming of this study in the evaluation of behavioral risk networks, and it needs to be continued in the future.

Author Contributions: Study conception and design: M.A. and H.A.; analysis and interpretation of the results: M.A. and W.X.; draft manuscript preparation: W.X. and J.H.; writing—review & editing, supervision: H.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Science Foundation of China Youth Science Foundation Project (Grant NO. 72004116) "Precise Quantification of Water Pollution Loads and Strategic Optimization of Emission Permit Allocation in Three Gorges Reservoir Area under the Constraints of Economic and Environmental Regulations" and the Hubei Province Humanities and Social Sciences Key Research Base Project (Grant NO. 2021-SDSG-05) "An Empirical Study on the Evaluation of Urban–Rural Integration Development and Spatial Pattern Evolution in Chongqing Western Region".

Data Availability Statement: All of the data, models, and code generated or used during the study appear in the submitted article. Some or all of the data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request. Informed consent was obtained from all subjects involved in the study.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Questionnaire on the Influence between Behavioral Risk Factors of Stakeholders in Hydropower Projects (Taking the Owner as an Example)

Dear Experts,

Hello! Thank you very much for taking time out of your busy schedule to do this questionnaire, we promise: the data obtained from this questionnaire will only be used for academic research, and absolutely no information provided by you will be disclosed without your permission.

In recent years, the state has advocated for the use of clean energy, and water resources power development as clean energy is vigorously promoted by the state; water resources power development needs to strengthen the infrastructure construction, such as: hydropower station construction, etc. When carrying out the infrastructure construction of large hydropower projects, involving the coordination of the interests of multiple participants, each participant takes some actions to maximize their own interests, their behavior may have an impact on other participants, and there are difficulties in achieving the quality, cost, schedule, and other goals of large hydropower projects.

The purpose of this research is to investigate the impact of risk factors on the behavior of stakeholders in large hydropower projects during the project construction, to analyze and identify key stakeholders and key behavior factors based on the survey data, and to provide help for the management of large hydropower projects during the project construction. We hope you can fill out the questionnaire truthfully and objectively, and we sincerely thank you for your cooperation.

Instructions for filling out:

1. The following content does not all need to be filled in; each survey object only needs to fill in a stakeholder behavior risk factors impact, such as: you in this project (mainly to the owners involved) only need to fill in Table 1.

2. Letter and number combinations appear in the questionnaire to explain; for example, S1R1 indicates that the stakeholder is the owner, and its corresponding behavioral risk factor is the difficulty of the payment of funds.

3. Explanation of the influence relationship between rows and columns of the table: the occurrence of behavioral risk factor S1R1 (column risk) can directly lead to (cause) the occurrence of or increase in S1R2 (row risk).

4. Please carefully judge one by one whether the following matrix of column risk factors has an impact on the row risk factors; if you think it will have a direct impact, click in the corresponding position of "☐" to select, and click again to cancel the selection.

Influenced Factors / **Influencing Factors**	S1R1 Difficulty in paying funds	S1R2 Proactive change request	S1R3 Untimely compensation for immigrant	S2R4 Design Changes	S2R5 Poor immigration planning and design	S2R6 The design does not consider ecological protection	S3R7 Project not delivered on schedule	S3R8 Construction costs exceeded budget
S1R1 Difficulty in paying funds	\	☐	☐	☐	☐	☐	☐	☐
S1R2 Proactive change request	☐	\	☐	☐	☐	☐	☐	☐
S1R3 Untimely compensation for immigrant	☐	☐	\	☐	☐	☐	☐	☐

	S3R9 Construction quality not up to standard	S3R10 Inappropriate construction safety measures	S3R11 Poor awareness of environmental protection	S4R12 Lack of timely implementation monitoring	S4R13 Supervision process is not standardized	S5R14 Material and equipment quality is not up to standard	S5R15 Lack of timely supply of material and equipment	S5R16 Market price adjustment
S1R1 Difficulty in paying funds	☐	☐	☐	☐	☐	☐	☐	☐
S1R2 Proactive change request	☐	☐	☐	☐	☐	☐	☐	☐
S1R3 Untimely compensation for immigrant	☐	☐	☐	☐	☐	☐	☐	☐

	S6R17 Policy changes in adjustment	S6R18 Call off construction	S6R19 Poor coordination skills	S7R20 Creating Public Opinion	S7R21 Disrupting the construction site	S7R22 Not cooperating with demolition	S8R23 Not strictly enforcing environmental standards	S8R24 Request for additional environmentally friendly structures
S1R1 Difficulty in paying funds	☐	☐	☐	☐	☐	☐	☐	☐
S1R2 Proactive change request	☐	☐	☐	☐	☐	☐	☐	☐
S1R3 Untimely compensation for immigrant	☐	☐	☐	☐	☐	☐	☐	☐

S1—Owners; S2—Designer; S3—Contractors; S4—Supervisor; S5—Material and Equipment Suppliers; S6—Government; S7—Immigrant; S8—Environmental Departments.

Appendix B. Adjacency Matrix of Influence Relations of the Risk Network of Stakeholder Behavior in Hydropower Projects

	S1R1	S1R2	S1R3	S2R4	S2R5	S2R6	S3R7	S3R8	S3R9	S3R10	S3R11	S4R12	S4R13	S5R14	S5R15	S5R16	S6R17	S6R18	S6R19	S7R20	S7R21	S7R22	S8R23	S8R24
S1R1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0
S1R2	1	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S1R3	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	0	1	1	1	0	0
S2R4	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S2R5	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0
S2R6	0	1	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1
S3R7	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0
S3R8	1	0	0	0	0	0	1	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
S3R9	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
S3R10	0	1	0	1	0	0	1	1	1	0	0	0	0	0	0	0	1	1	0	1	1	0	0	1
S3R11	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1
S4R12	0	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0	1	1	0	1	1	0	1	0
S4R13	0	1	1	0	0	0	1	1	1	1	1	1	0	1	1	0	1	1	0	0	1	0	1	0
S5R14	0	1	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
S5R15	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
S5R16	1	0	0	1	0	0	1	1	1	0	0	0	0	1	1	0	1	0	0	1	0	0	0	0
S6R17	1	0	0	0	1	0	1	1	0	0	0	0	0	0	0	1	0	1	0	0	1	1	0	1
S6R18	0	1	0	1	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	1	1	0	0	0
S6R19	1	0	1	0	1	0	1	1	0	0	0	0	0	0	0	1	1	0	0	1	1	1	0	0
S7R20	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	0	1
S7R21	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	1	1	0	1	0	1	0	1
S7R22	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	1
S8R23	0	1	0	1	0	1	0	1	1	0	1	0	1	1	0	0	1	1	0	1	1	0	0	1
S8R24	1	1	0	1	0	0	1	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0

References

1. Grubler, A.; Wilson, C.; Bento, N.; Boza-Kiss, B.; Krey, V.; McCollum, D.L.; Rao, N.D.; Riahi, K.; Rogelj, J.; De Stercke, S.; et al. A low energy demand scenario for meeting the 1.5 °C target and sustainable development goals without negative emission technologies. *Nat. Energy* **2018**, *3*, 515–527. [CrossRef]
2. Gielen, D.; Boshell, F.; Saygin, D.; Bazilian, M.D.; Wagner, N.; Gorini, R. The role of renewable energy in the global energy transformation. *Energy Strategy Rev.* **2019**, *24*, 38–50. [CrossRef]
3. Ometto, J.P.; Cimbleris, A.C.P.; dos Santos, M.A.; Rosa, L.P.; Abe, D.; Tundisi, J.G.; Stech, J.L.; Barros, N.; Roland, F. Carbon emission as a function of energy generation in hydroelectric reservoirs in Brazilian dry tropical biome. *Energy Policy* **2013**, *58*, 109–116. [CrossRef]
4. Chang, X.; Liu, X.; Zhou, W. Hydropower in China at present and its further development. *Energy* **2010**, *35*, 4400–4406. [CrossRef]
5. Ma, L.; Wang, L.; Wu, K.-J.; Tseng, M.-L.; Chiu, A.S.F. Exploring the Decisive Risks of Green Development Projects by Adopting Social Network Analysis under Stakeholder Theory. *Sustainability* **2018**, *10*, 2104. [CrossRef]
6. Siraj, N.B.; Fayek, A.R. Risk Identification and Common Risks in Construction: Literature Review and Content Analysis. *J. Constr. Eng. Manag.* **2019**, *145*, 03119004. [CrossRef]
7. Ashkanani, S.; Franzoi, R. Gaps in megaproject management system literature: A systematic overview. *Eng. Constr. Arch. Manag.* **2022**. *ahead of print*. [CrossRef]
8. Liang, X.; Yu, T.; Guo, L. Understanding Stakeholders' Influence on Project Success with a New SNA Method: A Case Study of the Green Retrofit in China. *Sustainability* **2017**, *9*, 1927. [CrossRef]
9. Aladag, H.; Isik, Z. The Effect of Stakeholder-Associated Risks in Mega-Engineering Projects: A Case Study of a PPP Airport Project. *IEEE Trans. Eng. Manag.* **2020**, *67*, 174–186. [CrossRef]
10. Wang, Q.; Zuo, W.; Li, Q. Engineering Harmony under Multi-Constraint Objectives: The Perspective of Meta-Analysis. *J. Civ. Eng. Manag.* **2020**, *26*, 131–146. [CrossRef]
11. Wu, D.; Lambert, J.H. Engineering Systems and Risk Analytics. *Risk Anal.* **2020**, *40*, 1–7. [CrossRef] [PubMed]
12. Ma, L.; Zhang, X.; Wang, H.; Qi, C. Characteristics and Practices of Ecological Flow in Rivers with Flow Reductions Due to Water Storage and Hydropower Projects in China. *Water* **2018**, *10*, 1091. [CrossRef]
13. Yang, M.; Chen, H.; Xu, Y.; Gong, W. Stakeholder-Associated Risks and Their Interactions in PPP Projects: Social Network Analysis of a Water Purification and Sewage Treatment Project in China. *Adv. Civ. Eng.* **2020**, *2020*, 8897196. [CrossRef]
14. Keshk, A.M.; Maarouf, I.; Annany, Y. Special studies in management of construction project risks, risk concept, plan building, risk quantitative and qualitative analysis, risk response strategies. *Alex. Eng. J.* **2018**, *57*, 3179–3187. [CrossRef]
15. Balta, S.; Birgonul, M.T.; Dikmen, I. Buffer Sizing Model Incorporating Fuzzy Risk Assessment: Case Study on Concrete Gravity Dam and Hydroelectric Power Plant Projects. *ASCE-ASME J. Risk Uncertain. Eng. Syst. Part A Civ. Eng.* **2018**, *4*, 04017039. [CrossRef]
16. Pehlivan, S.; Oztemir, A.E. Integrated Risk of Progress-Based Costs and Schedule Delays in Construction Projects. *Eng. Manag. J.* **2018**, *30*, 108–116. [CrossRef]
17. Urgilés, P.; Claver, J.; Sebastián, M.A. Analysis of the Earned Value Management and Earned Schedule Techniques in Complex Hydroelectric Power Production Projects: Cost and Time Forecast. *Complexity* **2019**, *2019*, 3190830. [CrossRef]
18. Su, H.; Yang, M.; Kang, Y. Comprehensive Evaluation Model of Debris Flow Risk in Hydropower Projects. *Water Resour. Manag.* **2015**, *30*, 1151–1163. [CrossRef]
19. Gao, J.; Ren, H.; Cai, W. Risk assessment of construction projects in China under traditional and industrial production modes. *Eng. Constr. Archit. Manag.* **2019**, *26*, 2147–2168. [CrossRef]

20. Zheng, Q.; Shen, S.-L.; Zhou, A.; Lyu, H.-M. Inundation risk assessment based on G-DEMATEL-AHP and its application to Zhengzhou flooding disaster. *Sustain. Cities Soc.* **2022**, *86*, 104138. [CrossRef]
21. Zhou, J.-L.; Zhe-Hua, B.; Sun, Z.-Y. Safety Assessment of High-Risk Operations in Hydroelectric-Project Based on Accidents Analysis, SEM, and ANP. *Math. Probl. Eng.* **2013**, *2013*, 530198. [CrossRef]
22. Yu, Y.; Darko, A.; Chan, A.P.C.; Chen, C.; Bao, F. Evaluation and Ranking of Risk Factors in Transnational Public–Private Partnerships Projects: Case Study Based on the Intuitionistic Fuzzy Analytic Hierarchy Process. *J. Infrastruct. Syst.* **2018**, *24*, 04018028. [CrossRef]
23. Thevendran, V.; Mawdesley, M.J. Perception of human risk factors in construction projects: An exploratory study. *Int. J. Proj. Manag.* **2004**, *22*, 131–137. [CrossRef]
24. Chan, E.H.W.; Au, M.C.Y. Building contractors' behavioural pattern in pricing weather risks. *Int. J. Proj. Manag.* **2007**, *25*, 615–626. [CrossRef]
25. Shen, W.; Tang, W.; Yu, W.; Duffield, C.F.; Hui, F.K.P.; Wei, Y.; Fang, J. Causes of contractors' claims in international engineering-procurement-construction projects. *J. Civ. Eng. Manag.* **2017**, *23*, 727–739. [CrossRef]
26. Xiang, P.; Jia, F.; Li, X. Critical Behavioral Risk Factors among Principal Participants in the Chinese Construction Industry. *Sustainability* **2018**, *10*, 3158. [CrossRef]
27. Wang, T.; Gao, S.; Li, X.; Ning, X. A meta-network-based risk evaluation and control method for industrialized building construction projects. *J. Clean. Prod.* **2018**, *205*, 552–564. [CrossRef]
28. Wu, G.; Zuo, J.; Zhao, X. Incentive Model Based on Cooperative Relationship in Sustainable Construction Projects. *Sustainability* **2017**, *9*, 1191. [CrossRef]
29. Adeleke, A.Q.; Bahaudin, A.Y.; Kamaruddeen, A.M.; A Bamgbade, J.; Salimon, M.G.; Khan, M.W.A.; Sorooshian, S. The Influence of Organizational External Factors on Construction Risk Management among Nigerian Construction Companies. *Saf. Health Work* **2018**, *9*, 115–124. [CrossRef]
30. Feng, J.; Wang, Y.; Zhang, K. Evaluation of the Quality Supervision System for Construction Projects in China Considering the Quality Behavior Risk Transmission. *Symmetry* **2020**, *12*, 1660. [CrossRef]
31. Shin, N.; Yoo, J.-S.; Kwon, I.-W.G. Fostering Trust and Commitment in Complex Project Networks through Dedicated Investment in Partnership Management. *Sustainability* **2020**, *12*, 10397. [CrossRef]
32. Quatman, C.; Chelladurai, P. Social Network Theory and Analysis: A Complementary Lens for Inquiry. *J. Sport Manag.* **2008**, *22*, 338–360. [CrossRef]
33. Wrzus, C.; Hänel, M.; Wagner, J.; Neyer, F.J. Social network changes and life events across the life span: A meta-analysis. *Psychol. Bull.* **2013**, *139*, 53–80. [CrossRef]
34. Ghafouri, H.B.; Mohammadhassanzadeh, H.; Shokraneh, F.; Vakilian, M.; Farahmand, S. Social network analysis of Iranian researchers on emergency medicine: A sociogram analysis. *Emerg. Med. J.* **2014**, *31*, 619–624. [CrossRef]
35. Feng, P.; Sun, D.; Gong, Z. A Case Study of Pyramid Scheme Finance Flow Network Based on Social Network Analysis. *Sustainability* **2019**, *11*, 4370. [CrossRef]
36. Loosemore, M. Social network analysis: Using a quantitative tool within an interpretative context to explore the management of construction crises. *Eng. Constr. Arch. Manag.* **1998**, *5*, 315–326. [CrossRef]
37. Lin, S.-C. An Analysis for Construction Engineering Networks. *J. Constr. Eng. Manag.* **2015**, *141*, 04014096. [CrossRef]
38. Herrera, R.F.; Mourgues, C.; Alarcón, L.F.; Pellicer, E. Understanding Interactions between Design Team Members of Construction Projects Using Social Network Analysis. *J. Constr. Eng. Manag.* **2020**, *146*, 1–13. [CrossRef]
39. Tang, H.; Wang, G.; Miao, Y.; Zhang, P. Managing Cost-Based Risks in Construction Supply Chains: A Stakeholder-Based Dynamic Social Network Perspective. *Complexity* **2020**, *2020*, 8545839. [CrossRef]
40. Lu, W.; Xu, J.; Söderlund, J. Exploring the Effects of Building Information Modeling on Projects: Longitudinal Social Network Analysis. *J. Constr. Eng. Manag.* **2020**, *146*, 04020037. [CrossRef]
41. He, Z.; Huang, D.; Zhang, C.; Fang, J. Toward a Stakeholder Perspective on Social Stability Risk of Large Hydraulic Engineering Projects in China: A Social Network Analysis. *Sustainability* **2018**, *10*, 1223. [CrossRef]
42. Wang, Y.; Wang, Y.; Wu, X.; Li, J. Exploring the Risk Factors of Infrastructure PPP Projects for Sustainable Delivery: A Social Network Perspective. *Sustainability* **2020**, *12*, 4152. [CrossRef]
43. Lee, C.; Won, J.W.; Jang, W.; Jung, W.; Han, S.H.; Kwak, Y.H. Social conflict management framework for project viability: Case studies from Korean megaprojects. *Int. J. Proj. Manag.* **2017**, *35*, 1683–1696. [CrossRef]
44. Xia, N.; Zhong, R.; Wu, C.; Wang, X.; Wang, S. Assessment of Stakeholder-Related Risks in Construction Projects: Integrated Analyses of Risk Attributes and Stakeholder Influences. *J. Constr. Eng. Manag.* **2017**, *143*, 04017030. [CrossRef]
45. Zhang, S.; Pan, F.; Wang, C.; Sun, Y.; Wang, H. BIM-Based Collaboration Platform for the Management of EPC Projects in Hydropower Engineering. *J. Constr. Eng. Manag.* **2017**, *143*, 0001403. [CrossRef]
46. Ding, J.; Chen, C.; An, X.; Wang, N.; Zhai, W.; Jin, C. Study on Added-Value Sharing Ratio of Large EPC Hydropower Project Based on Target Cost Contract: A Perspective from China. *Sustainability* **2018**, *10*, 3362. [CrossRef]
47. Mok, K.Y.; Shen, G.Q.; Yang, R. Stakeholder complexity in large scale green building projects. *Eng. Constr. Arch. Manag.* **2018**, *25*, 1454–1474. [CrossRef]
48. Sadkowska, J. Difficulties in Building Relationships with External Stakeholders: A Family-Firm Perspective. *Sustainability* **2018**, *10*, 4557. [CrossRef]

49. Amadi, C.; Carrillo, P.; Tuuli, M. PPP projects: Improvements in stakeholder management. *Eng. Constr. Arch. Manag.* **2019**, *27*, 544–560. [CrossRef]
50. Daniel, E.I.; Pasquire, C.; Dickens, G. Development of Approach to Support Construction Stakeholders in Implementation of the Last Planner System. *J. Manag. Eng.* **2019**, *35*, 04019018. [CrossRef]
51. Luo, L.; Shen, Q.G.; Xu, G.; Liu, Y.; Wang, Y. Stakeholder-Associated Supply Chain Risks and Their Interactions in a Prefabricated Building Project in Hong Kong. *J. Manag. Eng.* **2019**, *35*, 04019018. [CrossRef]
52. Bahadorestani, A.; Karlsen, J.T.; Farimani, N.M. Novel Approach to Satisfying Stakeholders in Megaprojects: Balancing Mutual Values. *J. Manag. Eng.* **2020**, *36*, 04019047. [CrossRef]
53. He, Z.; Huang, D.; Fang, J.; Wang, B. Stakeholder Conflict Amplification of Large-Scale Engineering Projects in China: An Evolutionary Game Model on Complex Networks. *Complexity* **2020**, *2020*, 9243427. [CrossRef]
54. Nguyen, V.T.; Do, S.T.; Vo, N.M.; Nguyen, T.A.; Pham, S.V.H.; Vignali, V. An Analysis of Construction Failure Factors to Stakeholder Coordinating Performance in the Finishing Phase of High-Rise Building Projects. *Adv. Civ. Eng.* **2020**, *2020*, 6633958. [CrossRef]
55. Jia, L.; Qian, Q.K.; Meijer, F.; Visscher, H. Stakeholders' Risk Perception: A Perspective for Proactive Risk Management in Residential Building Energy Retrofits in China. *Sustainability* **2020**, *12*, 2832. [CrossRef]
56. Wen, S.; Qiang, G. Managing Stakeholder Concerns in Green Building Projects With a View Towards Achieving Social Sustainability: A Bayesian-Network Model. *Front. Environ. Sci.* **2022**, *10*, 290. [CrossRef]
57. Yang, R.J.; Zou, P.X.W. Stakeholder-associated risks and their interactions in complex green building projects: A social network model. *Build. Environ.* **2014**, *73*, 208–222. [CrossRef]
58. Wu, Z.; Nisar, T.; Kapletia, D.; Prabhakar, G. Risk factors for project success in the Chinese construction industry. *J. Manuf. Technol. Manag.* **2017**, *28*, 850–866. [CrossRef]
59. Xia, N.; Zou, P.X.W.; Liu, X.; Wang, X.; Zhu, R. A hybrid BN-HFACS model for predicting safety performance in construction projects. *Saf. Sci.* **2018**, *101*, 332–343. [CrossRef]
60. Darvishi, S.; Jozi, S.A.; Malmasi, S.; Rezaian, S. Environmental risk assessment of dams at constructional phase using VIKOR and EFMEA methods (Case study: Balarood Dam, Iran). *Hum. Ecol. Risk Assess. Int. J.* **2019**, *26*, 1087–1107. [CrossRef]
61. Barghi, B.; Sikari, S.S. Qualitative and quantitative project risk assessment using a hybrid PMBOK model developed under uncertainty conditions. *Heliyon* **2020**, *6*, e03097. [CrossRef] [PubMed]
62. Huang, N.; Bai, L.; Wang, H.; Du, Q.; Shao, L.; Li, J. Social Network Analysis of Factors Influencing Green Building Development in China. *Int. J. Environ. Res. Public Health* **2018**, *15*, 2684. [CrossRef] [PubMed]
63. Ganbat, T.; Chong, H.-Y.; Liao, P.-C.; Leroy, J. Identification of critical risks in international engineering procurement construction projects of Chinese contractors from the network perspective. *Can. J. Civ. Eng.* **2020**, *47*, 1359–1371. [CrossRef]
64. Zhou, J.-L.; Bai, Z.-H.; Sun, Z.-Y. A hybrid approach for safety assessment in high-risk hydropower-construction-project work systems. *Saf. Sci.* **2014**, *64*, 163–172. [CrossRef]
65. Agarwal, S.S.; Kansal, M.L. Risk based initial cost assessment while planning a hydropower project. *Energy Strat. Rev.* **2020**, *31*, 100517. [CrossRef]
66. Dixit, S.; Stefańska, A.; Musiuk, A.; Singh, P. Study of enabling factors affecting the adoption of ICT in the Indian built environment sector. *Ain Shams Eng. J.* **2021**, *12*, 2313–2319. [CrossRef]
67. Xie, L.; Han, T.; Skitmore, M. Governance of Relationship Risks in Megaprojects: A Social Network Analysis. *Adv. Civ. Eng.* **2019**, *2019*, 1426139. [CrossRef]
68. Yang, X.; Zhang, J.; Zhao, X. Factors Affecting Green Residential Building Development: Social Network Analysis. *Sustainability* **2018**, *10*, 1389. [CrossRef]
69. Li, C.Z.; Hong, J.; Xue, F.; Shen, G.Q.; Xu, X.; Mok, M.K. Schedule risks in prefabrication housing production in Hong Kong: A social network analysis. *J. Clean. Prod.* **2016**, *134*, 482–494. [CrossRef]
70. Valentin, V.; Naderpajouh, N.; Abraham, D.M. Integrating the Input of Stakeholders in Infrastructure Risk Assessment. *J. Manag. Eng.* **2018**, *34*, 04018042. [CrossRef]
71. Zhang, S.; Fang, Y. Research on Construction Project Organization Based on Social Network Analysis. *Wirel. Pers. Commun.* **2018**, *102*, 1867–1877. [CrossRef]
72. Yuan, M.; Li, Z.; Li, X.; Luo, X. Managing stakeholder-associated risks and their interactions in the life cycle of prefabricated building projects: A social network analysis approach. *J. Clean. Prod.* **2021**, *323*, 129102. [CrossRef]