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Research on Risk Management in the Decision-Making Stage of a Project Based on DPSIR

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Abstract: With the growth of the construction industry, risk management in construction projects has garnered significant attention from the academic community. Effective risk management during the decision-making stage can greatly enhance project management efficiency. This paper integrates the AHP-entropy value method and constructs a risk management model based on the DPSIR framework for construction projects. The model is applied to evaluate and analyze the risk level of the decision-making stage in a navigation and electricity hub project in Chongqing Municipality. The results demonstrate the scientific validity and effectiveness of the proposed model.

Keywords: DPSIR; Construction projects; Decision stage; Risk management; AHP-entropy method

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1. Introduction

As the economy continues to grow, the construction industry is expanding rapidly [1]. However, construction projects are increasingly exposed to various risks [2]. Throughout a project's life cycle, economic losses resulting from potential natural disasters, accidents, and other unforeseen events are collectively referred to as engineering risks [3]. These risks not only lead to increased project costs and delays but may also impact the overall benefits and social reputation of the project. Therefore, effective risk management in construction projects is essential.

Risk management involves maximizing safety and security through economic and technical approaches, including risk identification, assessment, evaluation, and preventive measures [4]. In construction projects, risk management is typically implemented through risk analysis and the development of mitigation strategies. Managing risks during the decision-making stage enables early identification and assessment of potential risks, facilitating optimal resource allocation [5]. To ensure the smooth implementation of construction projects and the achievement of their intended objectives, this paper examines risk management in the decision-making stage.

Existing research on construction project risk management has explored various approaches. Zhou addressed cost risk in the construction stage by developing an AHP-DEMATEL model [6]. Hu *et al.* constructed a system dynamics (SD) risk model for prefabricated building projects under the PPP model by identifying potential risk factors at each stage of the project life cycle through a risk breakdown structure (RBS) [7]. Zhu applied a fuzzy risk evaluation model to analyze the potential risks associated with green building applications from a construction perspective [8]. Xiang and Zhang processed dispersed risk evaluation data into different degrees of gray assessment values by analyzing the mutual influence of indicators [9]. Serpell *et al.* developed an organizational maturity model to effectively evaluate risk management capacity within construction organizations [10]. Cai proposed a fuzzy multilevel gray evaluation method for assessing the risks of green building design, integrating fuzzy Delphi hierarchical analysis and gray theory [11]. Zhao *et al.* assessed the risk management maturity of Singaporean construction firms using triangular fuzzy numbers [12].

Despite extensive research on construction project risk management, some studies overlook the interrelationships among influencing factors, failing to consider the complex interactions within the system. The DPSIR model provides a comprehensive framework for identifying and analyzing risk factors in the decision-making stage of construction projects, allowing for a systematic evaluation of their interdependencies and impacts [13-16]. By incorporating the DPSIR model into risk management at the decision-making stage, project managers can systematically analyze risk factors, gain a holistic understanding of their interactions, and develop more scientifically sound and effective risk management strategies. Therefore, this paper introduces the DPSIR model into risk management research for the decision-making stage of construction projects. By integrating the AHP-entropy value method, it constructs a DPSIR-based risk management model tailored to the decision-making stage of construction projects. This study aims to provide a valuable reference for improving risk management practices during the decision-making stage of construction projects.

2. Construction of an indicator system for risk management at the decision-making stage based on DPSIR

2.1. Selection of risk management indicators

Driving force indicators: Driving force indicators encompass natural, social, and policy factors, which serve as key drivers for effective decision-making in construction projects. First, natural risks represent a major challenge for construction projects, including environmental degradation, geological changes, force majeure events (e.g., earthquakes, floods), shifts in transportation conditions, and extreme weather, all of which can significantly impact project timelines, costs, and quality. Second, various social factors influence project implementation. Social risks include local security conditions, religious beliefs and customs, immigration, and relocation issues, all of which may affect the smooth progress of a project. Additionally, with China's construction industry experiencing steady development, changes in policies, laws, and regulations may introduce uncertainties and legal risks, thereby influencing project decision-making and execution.

Pressure indicators: Pressure indicators reflect the external forces that influence effective decision-making in construction projects. Since the decision-making stage involves cross-departmental collaboration and complex technical interfaces, these indicators primarily stem from challenges in interdepartmental coordination and professional ethics. Such risk factors can lead to mismanagement, ultimately affecting the overall efficiency and success of a project.

State indicators: State indicators assess the economic and technical risk factors affecting construction projects under the influence of external pressures. Economically, large-scale investments, exchange rate fluctuations, interest rate adjustments, material price changes, and labor market shifts can escalate project costs, thereby impacting economic efficiency. Technically, discrepancies between decision-making assumptions and actual conditions may arise. Factors such as the feasibility of key technical solutions, the rationality of construction organization design, and the appropriateness of major building arrangements can pose challenges to project implementation, ultimately affecting technical feasibility and safety.

Impact indicators: Impact indicators evaluate the societal effects of a construction project post-completion, as anticipated during the decision-making stage. The objective of a construction project extends beyond economic maximization to achieving a balance among economic, social, and environmental goals. Risks related to project objectives primarily concern the ability to manage these targets effectively. If not properly addressed, these risks may prevent the project from meeting its expected goals, thereby influencing its final outcomes.

Response indicators: Response indicators assess the societal response to a construction project, including its demonstrative role and operational effectiveness post-completion. These factors influence public acceptance and the project's long-term benefits.

2.2. Construction of a risk management indicator system

Based on the selected risk management indicators, this study organizes and synthesizes existing evaluation frameworks for construction project risk management. By refining and optimizing the initial selection of indicators, it ultimately establishes a comprehensive risk management evaluation system for construction projects based on the DPSIR model, as illustrated in **Table 1**.

Table 1. Evaluation index system of risk management in the decision-making stage of a construction project based on DPSIR model

Objective level	Criterion level	Indicator level
Evaluation of risk management at the decision-making stage of construction projects	Driving	Environmental Degradation (D_1), Geological Conditions (D_2), Force Majeure (D_3), Transportation Conditions Change (D_4), Abnormal Climate Conditions (D_5), Local Security Level (D_6), Religious Beliefs and Customs (D_7), Resettlement and Relocation (D_8), Environmental Policy Changes (D_9), Local Protectionism (D_{10}), War and Conflict (D_{11})
	Pressure	Interdepartmental Coordination Capability (P_1), Professional Ethics Level (P_2)
	State	Exchange Rate Fluctuation (S_1), Interest Rate Adjustment (S_2), Construction Material Price Fluctuation (S_3), Labor Market Changes (S_4), Feasibility of Key Technical Schemes (S_5), Rationality of Construction Organization Design (S_6), Rationality of Main Building Layout (S_7)
	Impact	Target Management Capability of Construction Projects (I_1)
	Response	Demonstrative Role of Construction Projects (R_1), Operational Performance After Project Completion (R_2)

As shown in **Table 1**, the evaluation system is structured into three levels: the objective level, the criterion level, and the indicator level. These levels are used to assess the risk management capability of construction projects during the decision-making stage, as well as to identify and analyze specific risk factors. This framework provides essential theoretical support for subsequent management analysis and evaluation based on the analytic hierarchy process–entropy value method.

3. Analysis and evaluation of construction project risk management based on AHP-entropy method

3.1. Determination of indicator weights

3.1.1. AHP method for determining subjective weights of indicators

The AHP method decomposes complex decision-making problems into multiple levels, enabling systematic analysis and comparison. This approach helps determine the relative importance of each risk factor in risk management. Based on the risk management evaluation index system for the decision-making stage of a construction project, the matrix elements a_{ij} are obtained through expert assessment using the Delphi method. A discriminant matrix is then constructed, followed by normalization to derive the standard matrix.

$$A = \left(\overline{a_{ij}}\right)_{m\times n} \tag{1}$$

where $\overline{a_{ij}}$ denotes the matrix elements after normalization. Summing the matrix by rows yields:

$$\overline{w_i} = \sum_{j=1}^{n} \overline{a_{ij}} \tag{2}$$

After normalization, the subjective weight w_i of the indicator is determined and can be expressed as:

$$w_i = \frac{\overline{w_i}}{\sum_{j=1}^{n} \overline{w_i}} \tag{3}$$

3.1.2. Entropy value method for determining objective weights of indicators

The entropy value method is an objective weighting approach that evaluates the information entropy of indicators, effectively minimizing the influence of subjective factors on risk evaluation results. Based on the construction project risk management index system, this study applies the entropy value method to calculate the entropy values and corresponding weights of the data. The jth evaluator assesses the risk level of the ith indicator, resulting in b_{ij} and establishing the initial data matrix B:

$$B = \left(b_{ij}\right)_{m\times n} \tag{4}$$

The entropy value E_i of the ith indicator is calculated as:

$$E_i = -\frac{1}{\ln n}\sum_{j=1}^{m} \overline{b_{ij}} \ln\overline{b_{ij}} \tag{5}$$

where $\overline{b_{ij}}$ denotes the corrected matrix elements. Finally, the objective weight Q_i of the indicator is calculated as:

$$Q_i = \frac{1-E_i}{\sum_{i=1}^{n} 1-E_i} \tag{6}$$

3.1.3. Combined weight calculation based on hierarchical analysis-entropy value method

Subjective weights and objective weights are combined to get the combined weight vector. Comprehensively assign weights to the evaluation indicators to get the comprehensive weight W_i of the ith indicator as:

$$W_i = (1-k)w_i + kQ_i \tag{7}$$

where k is the correction coefficient, taking the value between 0 and 1. To ensure that the evaluation results are objective and accurate, with reference to existing literature, this paper compromises the value of k = 0.5 [17]. Therefore, the comprehensive weight of the indicators is:

$$W_i = 0.5w_i + 0.5Q_i \tag{8}$$

3.2. Construction of the risk evaluation matrix

Since the evaluation indicators of risk management in the decision-making stage of the construction project are all qualitative indicators, this paper develops the risk level through expert scoring, and transforms the qualitative indicators of risk management into quantitative indicators. The experts are organized to score the indicators, and the score of the pth expert on the ith risk evaluation indicator is set as c_{pi}, and according to the scoring results of the mth expert, the evaluation sample matrix C is obtained as:

$$C = \begin{bmatrix} c_{11} & c_{12} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ c_{m1} & c_{m2} & \cdots & c_{mn} \end{bmatrix} \quad (9)$$

3.3. Gray evaluation

3.3.1. Determining the evaluation gray class whitening weight function

Based on the statistical data, five evaluation gray intervals are selected, and their order is e = 1, 2, 3, 4, 5. e denotes extremely low risk, low risk, medium risk, high risk, and extremely high risk, respectively. The whitening weight function $f_e(c_{pi})$ is defined as follows:

(a) Type 1 gray "extremely low risk" with gray number ⊗ 1∈ [0,1,2], i.e.:

$$f_1(c_{pi}) = \begin{cases} c_{pi}, c_{pi} \in [0,1]; \\ 2 - c_{pi}, c_{pi} \in (1,2]; \\ 0, c_{pi} \in (-\infty,0) \cup (2,\infty) \end{cases} \quad (10)$$

(b) Type 2 gray "low risk" with gray number ⊗ 2∈ [0,2,4], i.e.:

$$f_2(c_{pi}) = \begin{cases} \frac{c_{pi}}{2}, c_{pi} \in [0,2]; \\ \frac{4-c_{pi}}{2}, c_{pi} \in (2,4]; \\ 0, c_{pi} \in (-\infty,0) \cup (4,\infty) \end{cases} \quad (11)$$

(c) Type 3 gray "medium risk" with gray number ⊗ 3∈ [0,3,6], i.e.:

$$f_3(c_{pi}) = \begin{cases} \frac{c_{pi}}{3}, c_{pi} \in [0,3]; \\ \frac{(6-c_{pi})}{3}, c_{pi} \in (3,6]; \\ 0, c_{pi} \in (-\infty,0) \cup (6,\infty) \end{cases} \quad (12)$$

(d) Type 4 gray "high risk" with gray number ⊗ 4∈ [0,4,8], i.e.:

$$f_4(c_{pi}) = \begin{cases} \frac{c_{pi}}{4}, c_{pi} \in [0,4]; \\ \frac{8-c_{pi}}{4}, c_{pi} \in (4,8]; \\ 0, c_{pi} \in (-\infty,0) \cup (8,\infty) \end{cases} \quad (13)$$

(e) Type 5 gray "extremely high risk" with gray number ⊗ 5∈ [0,5,10], i.e.:

$$f_5(c_{pi}) = \begin{cases} \frac{c_{pi}}{5}, c_{pi} \in [0,5]; \\ \frac{10-c_{pi}}{5}, c_{pi} \in (5,10]; \\ 0, c_{pi} \in (-\infty,0) \cup (10,\infty) \end{cases} \quad (14)$$

3.3.2. Calculating the gray evaluation coefficient

The evaluation gray number of the indicator *Gt* belonging to category *e* evaluation gray category is:

$$\mathrm{X} = \sum_{i=1}^{n} f_e\left(c_{pi}\right) \quad (15)$$

3.3.3. Calculating the gray evaluation weight vector and weight matrix

The gray evaluation weights of all experts claiming to belong to category *e* with respect to the evaluation indicator

Gt are:

$$r_e = \frac{X_e}{X} \tag{16}$$

The gray evaluation weight vector $r_e = (r_1, r_2, r_3, r_4, r_5)$ is obtained as the gray evaluation weight matrix R as:

$$R = \begin{bmatrix} r_{g1} \\ r_{g2} \\ \vdots \\ r_{gt} \end{bmatrix} = \begin{bmatrix} r_{g11} & r_{g12} & r_{g13} & r_{g14} & r_{g15} \\ r_{g21} & r_{g22} & r_{g23} & r_{g24} & r_{g25} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ r_{gt1} & r_{gt2} & r_{gt3} & r_{gt4} & r_{gt5} \end{bmatrix} \tag{17}$$

3.3.4. Comprehensive evaluation

The weight of the indicator *Gt* with respect to the previous level indicator *G* is *U*. The evaluation result of *G* is denoted as *D*. Then we have:

$$D = \mathrm{U} \times \mathrm{R} = \left(d_{g1}, d_{g2}, d_{g3}, d_{g4}, d_{g5}\right) \tag{18}$$

The matrix of indicator evaluation results *T* is obtained as:

$$T = \begin{bmatrix} B_1 \\ B_2 \\ \vdots \\ B_5 \end{bmatrix} = \begin{bmatrix} d_{11} & d_{12} & d_{13} & d_{14} & d_{15} \\ d_{21} & d_{22} & d_{23} & d_{24} & d_{25} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ d_{51} & d_{52} & d_{53} & d_{54} & d_{55} \end{bmatrix} \tag{19}$$

Comprehensive evaluation results are available:

$$Z = U \times T = (d_1, d_2, d_3, d_4, d_5) \tag{20}$$

4. Case study

A navigation and power hub in Chongqing, China is a project that mainly focuses on shipping, combines navigation and power, and has comprehensive utilization of transportation, irrigation, water supply, and breeding. This research takes this navigation hub project as an example to analyze the scientific and effectiveness of the risk management evaluation index system for the decision-making stage of construction projects based on the DPSIR model.

4.1. Risk management evaluation process

The risk management indicators are categorized into five levels, i.e., V = {very low risk ∈ [0,2], low risk ∈ [2,4], medium risk ∈ [4,6], high risk ∈ [6,8], and very high risk ∈ [8,10]}, for the risk scenario of the project at the decision-making stage. Five experts from each of the construction unit and the investment unit, totaling 10 people, were invited to score the indicators of the indicator layer. The weights are calculated according to the hierarchical analysis and entropy value method, and the weights of each indicator are calculated in turn to get the weights of the indicators of each structural layer, and the results are shown in **Table 2**.

Table 2. Summary of weight values of risk management indicators in the decision-making stage of a navigation hub project

Criterion level	Weight value	Indicator level	AHP weight value	Entropy method weight value	Comprehensive weight value
D	0.4804	D_1	0.0411	0.0403	0.0407
		D_2	0.0483	0.0492	0.04875
		D_3	0.0468	0.0475	0.04715
		D_4	0.0424	0.0422	0.0423
		D_5	0.0468	0.0465	0.04665
		D_6	0.0422	0.0408	0.0415
		D_7	0.0412	0.0412	0.0412
		D_8	0.0471	0.0454	0.04625
		D_9	0.0421	0.0402	0.04115
		D_{10}	0.0466	0.0472	0.0469
		D_{11}	0.0375	0.0382	0.03785
P	0.0853	P_1	0.0423	0.0397	0.041
		P_2	0.0454	0.0432	0.0443
S	0.3082	S_1	0.0461	0.0464	0.04625
		S_2	0.0402	0.0407	0.04045
		S_3	0.0477	0.0452	0.04645
		S_4	0.0407	0.0402	0.04045
		S_5	0.0469	0.0468	0.04685
		S_6	0.0432	0.0441	0.04365
		S_7	0.0434	0.0448	0.0441
I	0.0436	I_1	0.0434	0.0438	0.0436
R	0.0825	R_1	0.0402	0.0429	0.04155
		R_2	0.0401	0.0418	0.04095

In the decision-making stage, a total of 10 experts with experience in similar engineering projects in technology, economy, and management were invited to score the comprehensive risk management indexes in the decision-making stage of this navigation hub project. Based on the five levels of risk evaluation, the corresponding gray whitening weight function is established, which is denoted as $f1$, $f2$, $f3$, $f4$, $f5$, and its graph is shown in **Figure 1**.

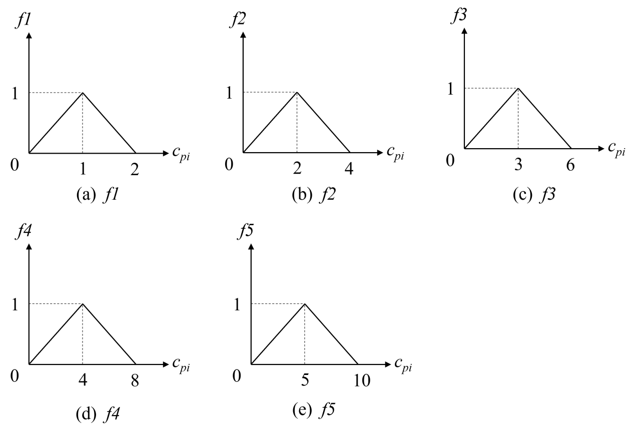

Figure 1. Whitening weight functions for various levels of risk

The evaluation coefficients are obtained according to the whitening weight function and the gray evaluation matrix is calculated as:

$$R = \begin{bmatrix} 0.1502 & 0.1137 & 0.1426 & 0.1477 & 0.2612 \\ 0.1713 & 0.2072 & 0.4131 & 0.1022 & 0.1420 \\ 0.1704 & 0.1542 & 0.2213 & 0.3104 & 0.2001 \\ 0.2911 & 0.4211 & 0.3072 & 0.1924 & 0.3002 \\ 0.2441 & 0.2043 & 0.2512 & 0.1076 & 0.1471 \end{bmatrix}$$

Based on Equation (18), the evaluation vector of the upper-level risk evaluation indicators can be calculated:

$$T = \begin{bmatrix} 0.0052 & 0.0061 & 0.0070 & 0.0067 & 0.0072 \\ 0.0022 & 0.0031 & 0.0041 & 0.0050 & 0.0021 \\ 0.0791 & 0.0962 & 0.0933 & 0.0062 & 0.0231 \\ 0.0182 & 0.0251 & 0.0270 & 0.0236 & 0.0023 \\ 0.1201 & 0.1102 & 0.4102 & 0.0109 & 0.0128 \end{bmatrix}$$

Based on Equation (20), the assessed value of the risk profile of this navigation hub project is obtained:

$$Z = (1.6237, 0.1022, 0.9245, 0.3926, 0.0901)^T$$

4.2. Analysis of results and recommendations

According to the assessment results, the main risks faced in the decision-making stage of the project include: risk of geological conditions D_2, abnormal climate D_5, force majeure D_3, rising prices of construction materials S_3, local protection D_{10}, exchange rate changes S_1, migration and relocation D_8, and infeasibility of key technical solutions S_5. In addition, there are some other risks, such as irrational arrangement of the main buildings S_7, risk of professional ethics P_2, and construction unreasonable organization design S_6, etc., which have smaller weights but still need to be handled with appropriate risk response measures.

Therefore, the primary risks at this stage stem from external drivers and decision-making uncertainties. Project risk managers should develop targeted countermeasures based on risk assessment results. It is crucial to implement effective risk management strategies, strictly enforce risk treatment plans, and conduct regular reporting and review.

For natural risks, environmental changes should be scientifically predicted and monitored, with contingency plans established accordingly. For example, designing adaptable building structures can help mitigate the impact of extreme weather conditions. In terms of social risks, enhancing communication with local communities can facilitate smoother migration and relocation processes, ensuring social harmony during project implementation.

To address political and policy risks, close monitoring of policy changes is essential, allowing for timely adaptation to new regulations and minimizing uncertainties. Economic risks, such as exchange rate and interest rate fluctuations, can be managed using financial instruments, while procurement costs for construction materials should be carefully controlled. Technical risks can be mitigated through thorough feasibility studies and scientifically sound construction planning, including the rational design of construction organization and the arrangement of major buildings.

At the decision-making stage, risk factors should be categorized based on their impact, prioritizing high-risk elements without neglecting lower-risk ones. To manage operational risks, professional ethics training should be reinforced to enhance managerial responsibility and professionalism. Performance evaluation and progress monitoring can help ensure project goals are met, while regular assessments of operational effectiveness will ensure the project continues to provide value and benefits to society.

5. Conclusion

Based on the DPSIR model, this paper constructs a risk management index system for the decision-making stage of construction projects and applies the hierarchical analysis-entropy value method to determine the final risk management model. A case study is conducted on a navigation and electricity hub project in Chongqing. The results indicate that the proposed risk management model effectively reflects the risk level at each structural level, providing a scientific basis for decision-making in construction project risk management. However, a limitation of this study is that the hierarchical analysis method may struggle to assess interrelated elements within complex systems, particularly in large-scale construction projects influenced by numerous factors. Future research could develop more advanced management models to better address the complexities of large-scale construction projects.

Disclosure statement

The author declares no conflict of interest.

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