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Research Article

Risk Assessment Method and Application of Urban River Ecological Governance Project Based on Cloud Model Improvement

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This study classifies risk factors and establishes the risk-evaluation index system for an urban river ecological management project. That system includes construction personnel risk, construction technology risk, construction management factor risk, construction duration factor risk, and other risks. A total of 23 indicators determine the level and standard of each indicator. This study proposes a risk index system that uses the cloud model evaluation method and explains that model's process. To demonstrate the risk evaluation methodology, it was applied to the ecological management project of Jinghe River in Jinghe New City, China. The results showed that: (1) the urban river ecological management project was subject to "a medium level of personnel risk, management risk, and construction period risk and a relatively high level of technical risk and other risks." According to the evaluation results, the overall risk level of the project was medium, which is consistent with the risk level of the Jinghe River ecological management project at the current stage. (2) The limitation of the subjective qualitative concept caused by the traditional fuzzy comprehensive evaluation was fully considered in the improved method, and the application of the cloud-model based improved method in risk evaluation of the urban river ecological management project significantly improved the reliability and visualization of the evaluation results. Finally, the urban river ecological management project in China was adopted as an example to prove that the model boasts high stability, and some corresponding countermeasures were also proposed. The research results are expected to provide valuable references and scientific criteria for implementing urban river ecological management projects.

1. Introduction

Urban river management engineering refers to a series of engineering measures undertaken to improve the river environment within or around urban areas, enhance water quality, protect water resources, prevent flooding disasters, and improve the ecological environment of riverbanks. These engineering projects aim to achieve a good water environment quality and sustainable environmental function of urban rivers by improving water quality, preventing and controlling water pollution, increasing water quantity regulation capacity, flood prevention and disaster mitigation, and restoring ecosystems. River ecological management in China has experienced four stages: exploration (1998–2001), germination (2002–2006), development (2007–2015), and improvement (2016–2023) [1]. Urban river ecological management projects, an essential part of river ecological management, have attracted significant attention from the Chinese government. Relevant statistics revealed that China boasts more than 70,000 rivers of all sizes. The Chinese government has adhered to the ecological river management philosophy of "water-saving priority, spatial balance, system governance, and two-handed efforts." The water conservancy departments and local governments in China have devoted massive manpower and material resources to urban river ecological management. They have also made remarkable achievements in constructing urban river water ecological civilization through various measures, such as riverway environmental management

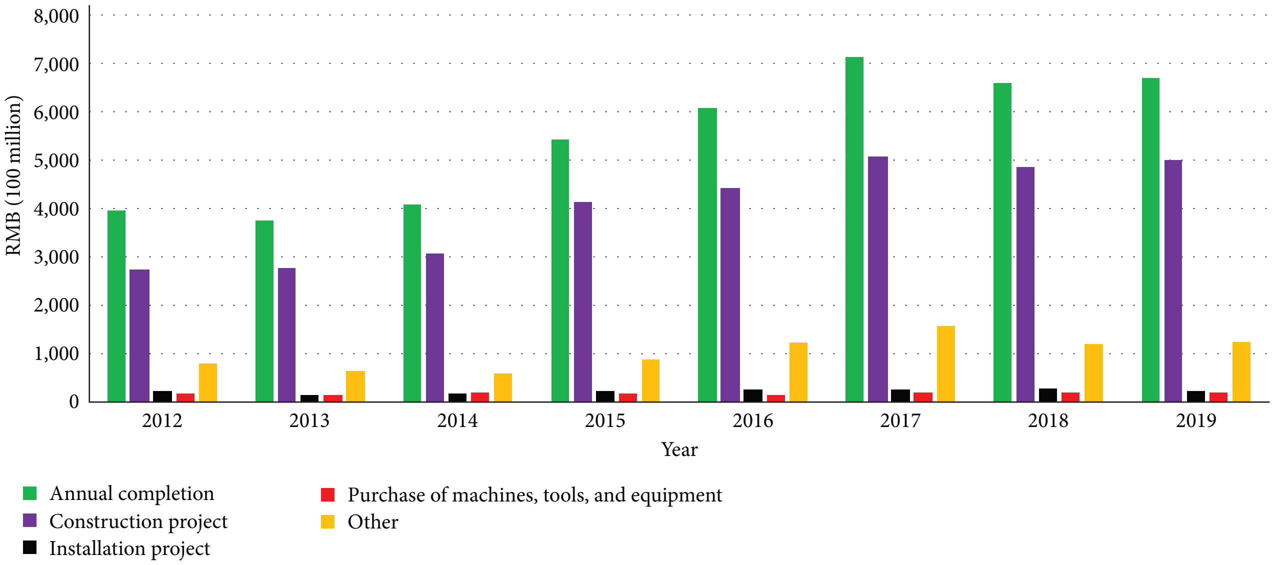


Figure 1: Statistics of China's investment in water conservancy projects in 2012–2019.

and water culture construction, thereby gaining significant recognition from society [2].

Besides their varying scales, water conservancy projects under construction in China involve great construction difficulty, a long construction period, and a great difference in the construction environment. Based on these negative factors, the projects face complicated and diversified risk factors in the construction process, which makes it difficult for researchers to predict and evaluate the risks at the construction stage [3]. According to statistics, China's investment in water conservancy construction reached Renminbi (RMB) 671.17 billion in 2019, an increase of RMB 10.91billion, or 1.7% from the previous year [4]. The overall investment in fixed assets of water conservancy showed an upward trend year by year (Figure 1). By the end of 2019, the cumulative investment of the projects under construction had totaled RMB 388.29 billion, with an investment completion rate of 67.2% [5]. Given the increasing construction rate and investment in water conservancy projects, how to evaluate the risk of water conservancy projects objectively and correctly is of great significance to the construction of water conservancy.

Assessing the risks of construction projects has become an essential part of engineering construction in recent years [6]. To minimize the risks of construction projects in a hazardous environment, various models, methods, and simulation approaches are employed by scholars for risk evaluation and control in such areas as project investment and financing [7, 8], construction [9, 10], and operation management [11], thus facilitating the improvement of project risk management. Meanwhile, risk evaluation at different working stages of water conservancy projects is studied by many scholars. Baker et al. [12] combine the research results of risk evaluation in similar projects with the actual needs established a complete risk-evaluation model for large-scale construction projects and realized the qualitative analysis of project risks. Hydro [13] conducted an investigation and data analysis of the risks in large-scale water conservancy and hydropower projects through a probability-based risk evaluation method and discovered that such projects, as a complete engineering system, involve various uncertain risk factors, which have a major impact on construction safety. Therefore, all possible risks should be evaluated before the construction, and relevant countermeasures and solutions should be put forward to tackle the risks.

Risk assessment in engineering projects is critical to ensuring the successful project implementation [14]. In recent years, cloud modeling has been widely applied as an emerging method for uncertainty modeling in engineering project risk assessment [15]. First, cloud modeling plays vital role in uncertainty modeling. The risk assessment process of engineering projects involves numerous uncertain factors, such as technical conditions, market environment, and policy regulations. Cloud modeling can transform these uncertain factors into membership functions to effectively describe their fuzziness and degree of uncertainty. By quantifying uncertainty, a more accurate evaluation and analysis of the risk level of engineering projects can be achieved [16]. Second, cloud modeling offers significant advantages in risk assessment and decision-making [17]. It can combine and transform the membership functions of various risk factors to obtain the overall risk membership function. Based on this membership function, risk assessment and decision analysis can be conducted to determine the feasibility and priority of projects under different risk conditions. The flexibility and adjustability of cloud modeling enable it to adapt to different types of engineering projects and provide decision-makers with comprehensive risk information. Additionally, cloud modeling is significant in knowledge acquisition and uncertainty handling [18]. Acquiring and integrating expert experience and actual data are crucial in engineering project risk assessment. Cloud modeling can effectively address the issue of knowledge acquisition by constructing membership functions and probability distribution functions based on expert experience and actual data, thus modeling and analyzing various uncertainty factors in the project [19]. This approach to knowledge acquisition is more in line with real-world situations and can better reflect the actual circumstances of project risks [20].

Based on the deficiencies identified in the risk assessment research of existing urban river ecological management projects, this study combines the analytic hierarchy process (AHP), fuzzy theory, and cloud model to develop a multilevel fuzzy comprehensive evaluation model for risk assessment of urban river ecological management projects based on the cloud model. This research evaluates risks in urban river ecological management projects and provides valuable references for addressing the other water engineering issues. The study is based on the fuzzy comprehensive evaluation method and introduces the cloud model to improve the risk assessment of urban river ecological management projects. The risk state can be reflected by improving three aspects: the cloud model of the comment set, the fuzzy relationship matrix improved by the cloud model, and the evaluation results represented by a cloud model consisting of three numerical characteristics (expectation, entropy, and hyper-entropy). Based on this method, the evaluation results consider the randomness and fuzziness of the data, making them more trustworthy and largely avoiding subjectivity.

The remainder of this paper is organized as follows: experimental data and methods are in Section 2, a case study is presented in Section 3, research results and analysis are in Section 4, a discussion of the results is presented in Section 5, and finally, the study is summarized in Section 6.

2. Experimental Data and Methods

2.1. Experimental Data. The first step in studying the urban river ecological management projects' risk is identifying project risk factors. Those factors are generally identified via the questionnaire method and the primary data collection method in statistics. This paper builds upon relevant research literature and uses interviews to avoid duplicated risk factors and identify risk factors characteristic of urban river ecological management projects.

2.1.1. Questionnaire Design. The core of the questionnaire surveyed respondents' views on the degree to which different risks affect urban river ecological management projects. The questionnaire's design followed practices established in the literature and was improved by supplementary suggestions from experts and project participants. The questionnaire consisted primarily of qualitative questions and employed a 9-point Likert scale. Respondents indicated the impact of each risk factor on a project with a score from 1 to 9, with higher numbers corresponding to the increased impact. The respondents indicated the extent to which each risk factor affects urban river ecological management projects according to their knowledge of such projects and relevant work experience by selecting the score corresponding to their answer.

2.1.2. Questionnaire Survey. Respondents were invited to complete questionnaires. The respondents were project managers, construction workers, technicians, and researchers who had worked on urban river ecological management projects.

According to the actual situation of the urban river ecological management project, the questionnaire was distributed in several ways. First, paper questionnaires were sent, and in-person interviews were conducted. This survey was narrowly focused to shorten survey completion time and allow for rapid data collection. Second, this study's questionnaire was converted into a Word document and emailed to respondents. Third, 100 questionnaires were distributed on the Questionnaire Star website. About 89 questionnaires were returned, of which 82 were valid. The effective recovery rate was thus 82%. Online surveys were convenient and involve no geographical restrictions, and the online questionnaire was, thus, this study's primary data collection method.

2.1.3. Risk Identification. After several rounds of identification, expert opinions were summarized, based on which the indicator system was formed as shown in Table 1.

2.2. Methods

2.2.1. AHP. AHP is a multiobjective decision analysis method combining the qualitative and quantitative analysis methods [22, 44]. The basic idea of AHP is to decompose a complex decision problem into multiple hierarchical factors and to determine their relative importance through comparison and judgment. These factors can be specific objectives, criteria, subcriteria, or decision alternatives, arranged in a hierarchical structure.

(1) Establishment of hierarchy

The research objects were divided into an appropriate hierarchy according to the risk-indicator system.

(2) Pairwise comparison and establishment of judgment matrix

After the indicator hierarchy was established, indicators at each level were compared for their importance, and their relative importance to the indicator at the upper level was judged. Based on the quantification of importance, a judgment matrix was established. The 1–9 scale method was used to express the relative importance of indicators.

(3) Determination of relative weight vector

The eigenvalues and eigenvectors were calculated. The maximum eigenvalue $\lambda_{\max}$ of the matrix and the corresponding eigenvector were calculated.

(4) Consistency test

Consistency indicator (CI):

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n - 1}. \quad (1)$$

Consistency ratio (CR):

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}}, \quad (2)$$

Table 1: Risk indicator system of urban river ecological management project U0.

Second-level risk indicator	Third-level risk indicator
Risk of construction personnel factor B1	Risk of low-technical level c11 [21–23] Risk of weak safety awareness c12 [24] Risk of practitioner qualification c13 [22] Risk of construction personnel slowdown c14 [25, 26]
Risk of construction technology factor B2	Risk of improper drawing design c21 [27, 28] Risk of engineering technology c22 [29] Risk of construction machines, tools, and equipment c23 [30] Risk of cross-construction c24 [31, 32] Risk of construction accidents c25 [33]
Risk of construction management factor B3	Risk of poor safety management c31 [28] Risk of defective construction party coordination c32 [34] Risk of poor design rationality of construction organization c33 [32] Risk of inadequate plan adjustment and engineering change c34 [35] Risk of deficient contract management and execution c35 [36] Risk of confusing organization setup c36 [37] Risk of poor management authority c37 [38]
Risk of construction period factor B4	Risk of document life cycle c41 [39] Risk of construction period c42 [28] Risk of construction period delay c43
Other risks B5	Risk of policies and laws c51 [32] Economic risk c52 [40] Social risk c53 [36, 41] Risk of natural disasters c54 [42, 43]

where n represents the number of risk-influencing factors, and RI denotes the average random number of consistency indicators.

$\mathrm{CR} < 0.1$ indicates that the judgment matrix is consistent. Otherwise, it is necessary to rescore and establish the judgment matrix until $\mathrm{CR} < 0.1$ is obtained.

2.2.2. Fuzzy Comprehensive Evaluation Method. Fuzzy comprehensive evaluation refers to a comprehensive evaluation of target transactions under fuzzy mathematics by considering various influencing factors. Its basic idea is to conduct a single-factor fuzzy evaluation of the deterministic and random factors that affect the measurement through measurement and testing. Finally, the conclusions of the single-factor evaluation are integrated through appropriate fuzzy algorithms, yielding the overall evaluation conclusion [20, 45]. The conduction of the fuzzy comprehensive evaluation method is briefly described as follows:

(1) Establishment of the factor set of evaluation objects $U = \{U_1, U_2, U_3, U_4 \ldots U_n\}$

The factor set, usually represented by U, consists of various factors affecting the evaluation objects. The element U_i represents the i factor affecting evaluation objects. Generally, these factors are fuzzy in varying degrees.

(2) Establishment of the comprehensive evaluation set of evaluation objects $V = \{V_1, V_2 \ldots V_k\}$

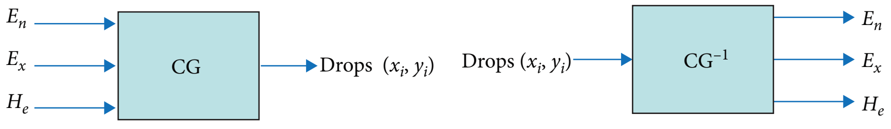
The evaluation set, generally represented by V, is composed of various possible evaluation results made by the evaluator. The element V_k represents the k evaluation result. At this step, the domain of the evaluation level is determined. More specifically, the evaluation indicators are graded (generally into (low, relatively low, medium, relatively high, and high)) reasonably and scientifically based on the impact of each evaluation indicator on risk evaluation results. The evaluation level is described in these fuzzy words.

(3) Establishment of the judgment matrix R

$$R = \begin{bmatrix} R_1 \\ R_2 \\ \vdots \\ R_m \end{bmatrix} = \begin{bmatrix} R_{11} & R_{12} & \cdots & R_{1k} \\ R_{21} & R_{22} & \cdots & R_{2k} \\ \vdots & \vdots & \vdots & \vdots \\ R_m & R_m & \cdots & R_{mk} \end{bmatrix}, \tag{3}$$

where R_{mk} $(i = 1, 2, \ldots, m; j = 1, 2, \ldots, k)$ denotes the membership degree of the m evaluation indicator to the k evaluation level, which reflects the fuzzy relationship expressed with the membership degree between the evaluation indicator and the evaluation level, m represents the m factor level, and k represents the k evaluation level.

(4) Calculation of the weight vector of evaluation indicators



(a) (b)

FIGURE 2: Cloud generator: (a) forward cloud generator and (b) backward cloud generator.

The weight of evaluation indicators can be calculated through various methods, such as AHP and expert consultation. Based on the research status, AHP was adopted in this paper to effectively calculate the weight vectors of evaluation indicators, expressed as follows:

$$A = (a_1, a_2, a_3, \ldots, a_n). \tag{4}$$

The weight calculated must meet the requirement of normalization: $\sum_{i=1}^{n} a_i = 1$.

(5) Fuzzy evaluation and drawing of the conclusion that $Y = A \cdot R$

In this part, the weight fuzzy matrix R obtained through calculation in Equation (3) is multiplied by the relational fuzzy matrix A obtained in Equation (4), yielding the fuzzy comprehensive evaluation results of risks. $Y = A \cdot R$ was assumed.

2.2.3. Cloud Model. Based on the traditional theories of probability statistics and fuzzy sets, the cloud model aims to realize the conversion between qualitative concepts and quantitative values [46]. In addition, more accurate knowledge can be mined to form the views of data, concepts, and knowledge, and the uncertain conversion between qualitative concepts and quantitative data will be realized [15]. The cloud model represents the primitive of natural language (a linguistic terms) [18]. The digital eigenvalues of the cloud model, namely expected value E_x, entropy E_n, and hyperentropy H_e, represent the mathematical properties of linguistic term. Therefore, the cloud model is generally expressed with SC (E_n, E_n, H_e).

(1) Computing of cloud model

The typical cloud generator of a cloud model can be classified as a forward cloud generator or a backward cloud generator [47]. This algorithm can be realized through Python as a fundamental algorithm in computing a cloud model.

Forward cloud generator: as the most fundamental cloud algorithm of a cloud model, the forward cloud generator is able to convert qualitative concepts into quantitative data [48]. The three digital eigenvalues of the cloud model are expressed as (E_n, E_n, H_e). Many cloud drops (x_i, y_i) could be generated through a particular algorithm, eventually forming a forward cloud generator, as shown in Figure 2(a).

Backward cloud generator: the backward cloud generator is the reverse process of the forward cloud generator in the cloud model, and it can convert the numerical values into the digital eigenvalues of the cloud. More specifically, expected value E_x, entropy E_n, and hyperentropy H_e are used to convert the quantitative data drop (x_i, y_i) to the qualitative information value [48]. The conversion process is shown in Figure 2(b).

In this study, the algorithm process of the backward cloud generator was realized through Python, leading to the cloud digital eigenvalues (E_x, E_n, H_e) of the risk evaluation of urban river ecological management projects.

(2) Comprehensive cloud model

Generally, the most basic cloud model comprises a standard normal cloud model, the left and right half clouds included as well as the whole cloud. Comprehensive cloud refers to a relatively high level of cloud after the combination of two or more cloud models of the same type. The comprehensive cloud generated is also referred to as the "parent cloud," and the clouds generating the parent cloud are called child clouds [49]. The three digital eigenvalues of the parent cloud can be obtained by calculating the multiple child clouds that constitute the parent cloud. If there were a total of n child clouds $U_0\{\mathrm{Cloud}_1(E_{x_1}, E_{n_1}, \mathrm{H}_{e_1}), \mathrm{Cloud}_2(E_{x_2}, \mathrm{E}_{n_2}, \mathrm{H}_{e_2}), \cdots, \mathrm{Cloud}_n(E_{x_n}, \mathrm{E}_{n_n}, \mathrm{H}_{e_n})\}$ of the same type in the domain U, then the comprehensive cloud generated should contain the domains of all the child clouds. The comprehensive cloud can be calculated by the following two formulas [49]:

$$\begin{aligned} E_x &= \frac{E_{x_1} \times E_{n_1} \times v_1 + E_{x_2} \times E_{n_2} \times v_2 + \ldots + E_{x_n} \times E_{n_n} \times v_0}{E_{n_1} \times v_1 + E_{n_2} \times v_2 + \ldots + E_{n_n} \times v_n} \\ E_n &= E_{n_1} \times v_1 \times n + E_{n_2} \times v_2 \times n + \ldots + E_{n_n} \times v_n \times n \\ H_e &= \frac{H_{e_1} \times E_{n_1} \times v_1 + H_{e_2} \times E_{n_2} \times v_2 + \ldots + H_{e_n} \times E_{n_n} \times v_n}{E_{n_1} \times v_1 + E_{n_2} \times v_2 + \ldots + E_{n_n} \times v_n}, \end{aligned} \tag{5}$$

$$\begin{aligned} E_x &= \sum_{i=1}^{n} E_{x_i v_i} \\ E_n &= \sqrt{\sum_{i=1}^{n} E_{n_i{}^2 v_i}} \\ E_e &= \sum_{i=1}^{n} E_{e_i v_i}. \end{aligned} \tag{6}$$

2.2.4. Establishment of Urban River Management Evaluation Model Based on Cloud Model. The risk evaluation system of urban river ecological management projects is a comprehensive evaluation system with multirisk indicator factors and a multilevel structure. By establishing a risk factor set and a risk evaluation set, a fuzzy comprehensive risk evaluation based on a cloud model has been adopted to calculate the weight vectors of the indicator factors at all levels using AHP. Then, half cloud and whole cloud were generated through the forward cloud generator and backward cloud generator, respectively, and the uppermost comprehensive cloud was obtained through comprehensive calculation. Detailed risk evaluation steps are described as follows:

Factor sets of risk indicators at all levels were, respectively, established in accordance with the risk-evaluation indicator system, and the final evaluation target U_0 and factor sets of evaluation indicators U_1 at each level were determined.

The weight of all risk-evaluation indicator factor sets was calculated through AHP. The weight of each level $V = \{V_1, V_2 \dots V_m\}$, among which $v_i \geq 0$, and $\sum_{i=1}^{m} v_i = 1, v_1 - v_m$ is the weight of each evaluation factor.

The evaluation set is designed to present the final quantitative evaluation result. With the evaluation set $w = \{w_1, w_2 \dots w_p\}$ determined, the risk level where the evaluation target U_0 lies could be finally determined.

The comprehensive cloud of the evaluation target U_0 was calculated as follows: first, the evaluation cloud of each risk-indicator factor at the bottom level was determined by processing the data obtained from the questionnaire; the second step was to acquire three digital eigenvalues (E_x, E_n, H_e) of each evaluation indicator factor at the bottom level utilizing a cloud generator; last, the comprehensive evaluation cloud of the upper indicator factors was determined v_i as the comprehensive cloud model based on indicator weight and evaluation cloud at all levels. The comprehensive evaluation cloud of the evaluation target U_0, that is to say the risk-evaluation cloud of urban river management projects, was finally obtained through repetitive calculation.

Cloud drops (x_i, φ_i) were generated using the forward cloud generator based on digital eigenvalues (E_x, E_n, H_e) of the comprehensive cloud model of the evaluation target U_0, based on which the cloud chart of the evaluation cloud was then drawn. In the end, the similarity value φ_i of the final evaluation result cloud and each evaluation set cloud was calculated in accordance with Equation (5), and the cloud model corresponding to the maximum similarity was the most similar cloud of the final evaluation result cloud. Next, the evaluation corresponding to the final evaluation result was reversely deduced, which was the risk level of urban river ecological management projects.

$$\begin{aligned} \varphi'_{ij} &= e^{\frac{\left(x_i - E_{x_j}\right)^2}{2\left(E_{n_j}\right)^2}} \\ \delta &= \frac{1}{n}\sum_{i=1}^{n}\varphi'_{ij}. \end{aligned} \tag{7}$$

TABLE 2: Evaluation level standards and cloud model parameters.

Performance level	Score	Cloud model parameter
Low risk	(0, 0.2)	(0, 0.0667, 0.01)
Relatively low risk	(0.2, 0.4)	(0.3, 0.0333, 0.01)
Medium risk	(0.4, 0.6)	(0.5, 0.0333, 0.01)
Relatively high risk	(0.6, 0.8)	(0.7, 0.0333, 0.01)
High risk	(0.8, 1)	(1, 0.0667, 0.01)

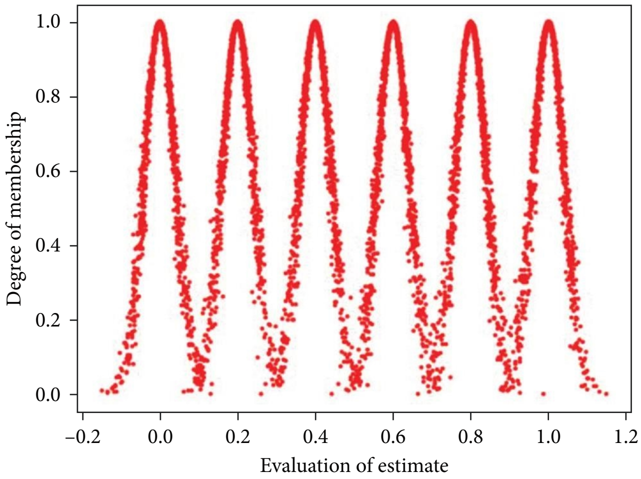


FIGURE 3: Cloud chart of evaluation level standards.

2.2.5. *Evaluation Set Cloudization.* In this study, the evaluation set consisting of qualitative risk levels was clouded to determine the evaluation result better. The bilateral constraint method was adopted to acquire the cloudization of the evaluation set. For the evaluation of $[C_{\min}, C_{\max}]$, the standard evaluation cloud algorithm is presented as follows:

$$\begin{aligned} E_x &= \frac{V_{\min} + V_{\max}}{2} \\ E_n &= \frac{V_{\max} - V_{\min}}{6} \\ H_e &= k, \end{aligned} \tag{8}$$

where k is a constant used to reflect the fuzziness of evaluation.

The risk-evaluation level of urban river ecological management projects was divided into five categories: high, relatively high, medium, relatively low, and low based on the characteristics of the cloud model and urban river ecological management projects (Table 2). In this study, [0,1] was set as the number field to define the evaluation set of setting quantitative-risk levels, which were equally divided by each evaluation. The cloud model of intermediate evaluation could be calculated by Equation (7). While evaluation clouds at both ends are calculated, “0” and “1” should be acted as the expectation of corresponding evaluation, respectively, and the entropy should be half that of the symmetric cloud model. Therefore, based on the evaluation level standards and cloud model parameters from Table 2, we have generated the cloud chart for project risk-assessment level standards (Figure 3).

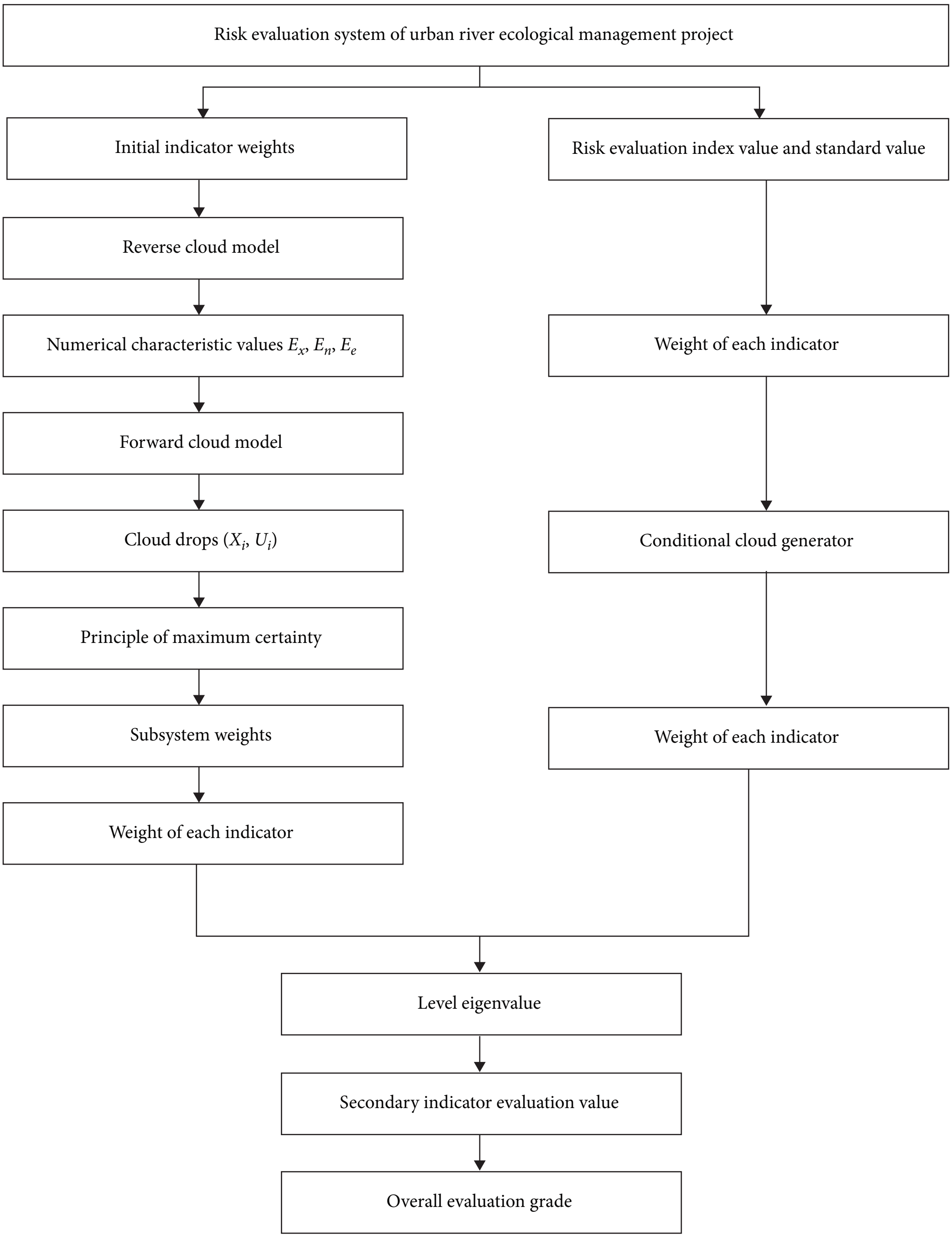


FIGURE 4: Cloud model evaluation process.

In this section, we constructed the evaluation model and presented a diagram illustrating the research method (Figure 4).

3. Case Study

Jinghe New City's Jinghe River flood control and ecological management project (referred to as the "Jinghe comprehensive management project" manages the Jinghe River from the Jiyuan Bridge (formerly Xiushi Du Bridge), upstream about 1.0 km, to the Xiantong railroad bridge. The project includes three subprojects: the Jinghe River embankment construction project, the Jinghe River beach management and ecological restoration project, and the Jinghe River outside the ecological protection project. The estimated total investment in the three subprojects is approximately

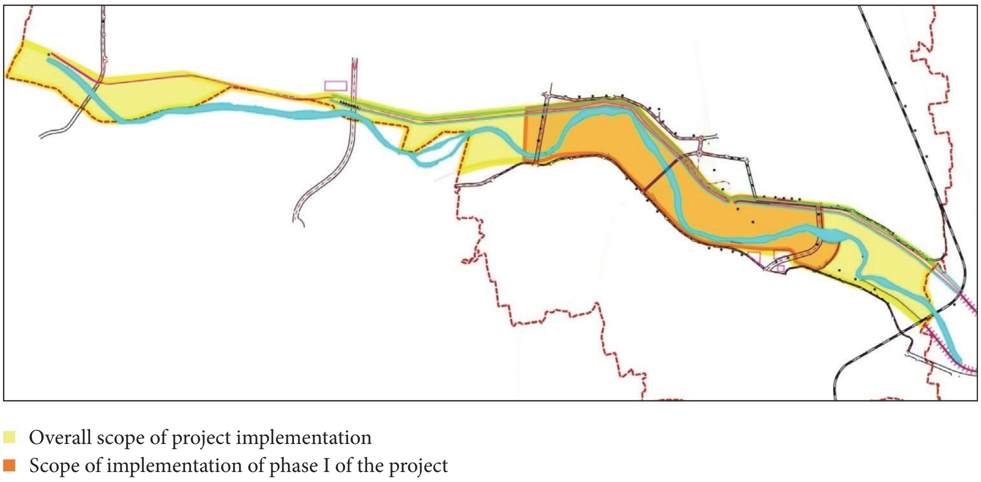


Figure 5: Jinghe comprehensive management project overview map.

Table 3: Weight of risk factor indicators of urban river ecological management projects.

Indicator	Weight	Indicator	Weight	Comprehensive weight
Risk of construction personnel factor B1	0.412808	Risk of low-technical level c11	0.291783	0.12045
		Risk of weak safety awareness c12	0.426391	0.176018
		Risk of lack of practitioner qualification c13	0.110897	0.045779
		Risk of construction personnel slowdown c14	0.170929	0.070561
Risk of construction technology B2	0.304994	Risk of improper drawing design c21	0.366979	0.111926
		Risk of inadequate engineering technology c22	0.218867	0.066753
		Risk of deficient construction machines, tools, and equipment c23	0.047311	0.01443
		Risk of cross-operation c24	0.068038	0.020751
		Risk of construction accidents c25	0.298806	0.091134
Risk of construction management factor B3	0.102653	Risk of poor safety management c31	0.048729	0.005002
		Risk of lack of construction party coordination (technical disclosure included) c32	0.300388	0.030836
		Risk of poor design rationality of construction organization c33	0.240744	0.024713
		Risk of defective plan adjustment and engineering change c34	0.06722	0.0069
		Risk of poor contract management and execution c35	0.156686	0.016084
		Risk of confusing organization setup c36	0.103098	0.010583
		Risk of insufficient management authority c37	0.083135	0.008534
Risk of construction period factor B4	0.069219	Risk of failure to document lifecycle c41	0.084144	0.005824
		Risk of overlong construction period c42	0.21092	0.0146
		Risk of construction period delay c43	0.704936	0.048795
Other risks B5	0.110326	Risk of breaking policies and laws c51	0.213367	0.02354
		Economic risk c52	0.313548	0.034592
		Social risk c53	0.074401	0.008208
		Risk of natural disasters c54	0.398684	0.043985

3.8 billion yuan. The project profile diagram is shown in Figure 5.

4. Research Results and Analysis

Weight values of all level risk factors were determined by AHP (Table 3).

The cloud digital eigenvalues of third-level indicators of urban river ecological management projects were calculated according to the backward cloud generator algorithm (Table 4).

After the cloud model of third-level evaluation indicators was acquired, the risk of construction personnel factor B1, risk of construction technology B2, risk of construction management factor B3, risk of construction period factor B4, and other risks B5 were, respectively, obtained by synthesizing the parent cloud at the upper level through the cloud model comprehensive calculation formula based on the weight of

Table 4: Cloud digital eigenvalues of risk evaluation third-level indicators of urban river ecological management.

Third-level risk indicator	Maximum cloud	Minimum cloud	Comprehensive cloud
Risk of low-technical level c11	0.6200, 0.0902, 0.0621	0.400, 0.0902, 0.0621	0.5100, 0.0925, 0.0809
Risk of weak safety awareness c12	0.7600, 0.1604, 0.0852	0.5800, 0.0902, 0.0621	0.6699, 0.1253, 0.0737
Risk of lack of practitioner qualification c13	0.4000, 0.1504, 0.0488	0.1800, 0.1203, 0.0502	0.2900, 0.1353, 0.0495
Risk of construction personnel slowdown c14	0.4600, 0.1103, 0.0289	0.2400, 0.1103, 0.0289	0.3500, 0.1103, 0.0289
Risk of improper drawing design c21	0.8399, 0.2206, 0.1198	0.6400, 0.2406, 0.1005	0.7400, 0.2306, 0.1101
Risk of inadequate engineering technology c22	0.5800, 0.1303, 0.0032	0.4600, 0.1604, 0.0475	0.5200, 0.1454, 0.0254
Risk of deficient construction machines, tools, and equipment c23	0.4400, 0.1103, 0.0289	0.2800, 0.1303, 0.0032	0.3600, 0.1203, 0.0061
Risk of cross-operation c24	0.6600, 0.1905, 0.0413	0.4600, 0.2406, 0.0097	0.5600, 0.2256, 0.0255
Risk of construction accidents c25	0.9000, 0.0000, 0.0000	0.6800, 0.0902, 0.0621	0.7900, 0.0451, 0.0311
Risk of poor safety management c31	0.6800 0.1804 0.0665	0.5400, 0.1905, 0.0413	0.6100, 0.1855, 0.0539
Risk of poor construction party coordination (technical disclosure included) c32	0.5800, 0.2306, 0.0939	0.4000, 0.2507, 0.1103	0.4900, 0.2406, 0.1021
Risk of poor design rationality of construction organization c33	0.8200, 0.0802, 0.0238	0.5800, 0.0802, 0.0238	0.700, 0.0802, 0.0238
Risk of insufficient plan adjustment and engineering change (risk of plan adjustment) c34	0.6600, 0.1604, 0.0476	0.4400, 0.1604, 0.0476	0.5500, 0.1604, 0.0476
Risk of defective contract management and execution c35	0.6000, 0.1002, 0.0703	0.4200, 0.1705, 0.0891	0.5100, 0.1353, 0.0797
Risk of confusing organization setup c36	0.4800, 0.2206, 0.0578	0.3400, 0.1604, 0.0852	0.4100, 0.1905, 0.0715
Risk of poor management authority c37	0.5200, 0.1303, 0.0032	0.2600, 0.1103, 0.0289	0.3900, 0.1203, 0.0160
Risk of failing to track document lifecycle c41	0.4800, 0.1303, 0.0032	0.3200, 0.1303, 0.0032	0.4000, 0.1303, 0.0032
Risk of overlong construction period c42	0.5800, 0.1303, 0.0707	0.3600, 0.1604, 0.0476	0.4700, 0.1454, 0.0592
Risk of construction period delay c43	0.6200, 0.1303, 0.0707	0.4400, 0.1404, 0.0574	0.5300, 0.1353, 0.0641
Risk of breaking policies and laws c51	0.9200, 0.0401, 0.0198	0.7200, 0.0802, 0.0238	0.8200, 0.0602, 0.0218
Economic risk c52	0.6800, 0.2406, 0.1381	0.4800, 0.1905, 0.1035	0.5800, 0.2156, 0.1208
Social risk c53	0.5600, 0.2106, 0.1366	0.3600, 0.1303, 0.0775	0.4600, 0.1705, 0.1071
Risk of natural disasters c54	0.7600, 0.1103, 0.0289	0.5000, 0.1027, 0.0703	0.6300, 0.1053, 0.0496

Table 5: Cloud digital eigenvalues of risk evaluation second-level indicators of urban river ecological management.

Second-level risk indicators	Comprehensive cloud
Risk of construction personnel B1	0.5264, 0.1153, 0.0654
Risk of construction technology B2	0.6766, 0.1700, 0.0573
Risk of construction management factor B3	0.5388, 0.1743, 0.0638
Risk of construction period factor B4	0.1725, 0.0852, 0.0176
Other risks B5	0.6422, 0.1481, 0.0703

second-level indicators. The cloud digital eigenvalues are presented in Table 5.

The cloud charts of five second-level evaluation indicators of urban river ecological management projects were generated through the forward cloud generator algorithm: the cloud chart of risk of personnel factor (Figure 6(a)), cloud chart of risk of technology factor (Figure 6(b)), cloud chart of risk of management factor (Figure 7(a)), cloud chart of risk of construction period factor (Figure 7(b)), and cloud chart of other risks (Figure 8(a)). The comparison relationships between their comprehensive cloud models and evaluation cloud models are presented in Figure 8(b).

The ultimate target of risk evaluation could be calculated based on Equation (8) with comprehensive clouds B1, B2, B3, B4, and B5 as the base cloud. The risk comprehensive cloud model of the urban river ecological management project was U0 (0.5618, 0.1426, and 0.0600). Figure 8(b) shows the comparison chart between the comprehensive evaluation cloud U0 and the evaluation cloud.

The evaluation result of the ecological river management project risk U0, as depicted in Figure 8(b), is represented by a stable pattern with dense cloud droplets. The evaluation cloud lay within the range of 0.4–0.8, close to the high level, but the risk level was medium. Cloud drops were relatively dense in cloud charts as shown in Figures 6(a)–8(a), thus the evaluation result was stable. The results showed that the levels of B1 personnel risk, B3 management risk, and B4 construction period risk were medium, while that of B2 technology risk and B5 other risks was relatively high.

The level of overall project risk U0 was medium. Strictly abiding by the fundamental construction procedures in the Jinghe River management project, the participants arranged the construction schedule scientifically and rationally in accordance with the actual situation to ensure its orderly implementation by means of planning, organization, coordination, and control. The close coordination of all parties reduced both the probability of underlying risks and the impact of the risks occurring.

As depicted in Figures 6(a), 7(a), and 7(b), the levels of B1 personnel risk, B3 management risk, and B4 construction period risk were assessed as medium.

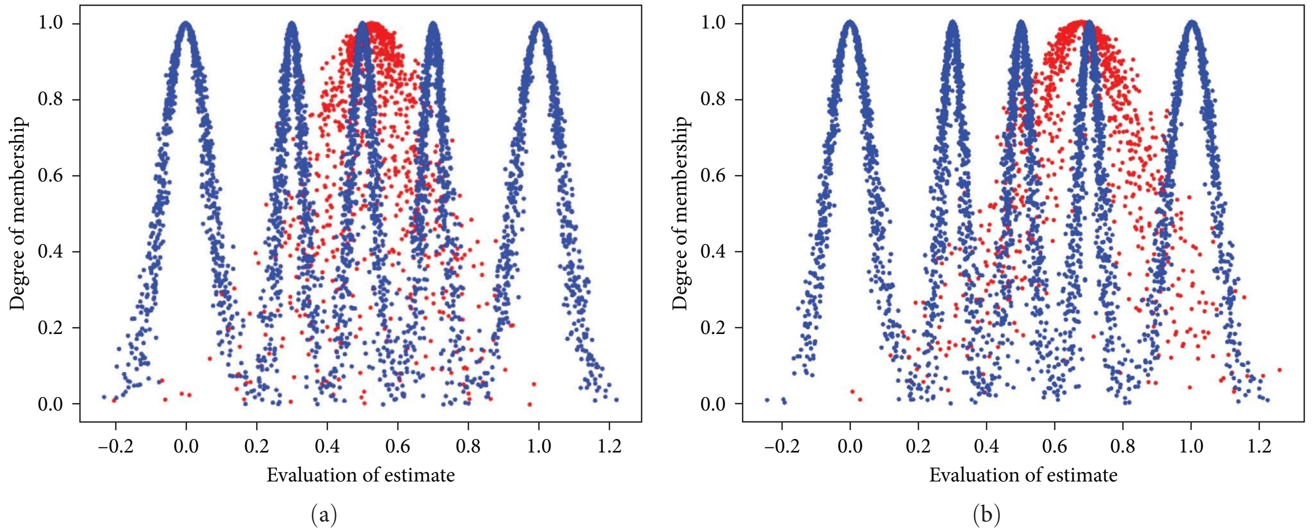


Figure 6: (a) Comparison chart of personnel factor risk and the evaluation cloud. (b) Comparison chart of technology factor risk and the evaluation cloud.

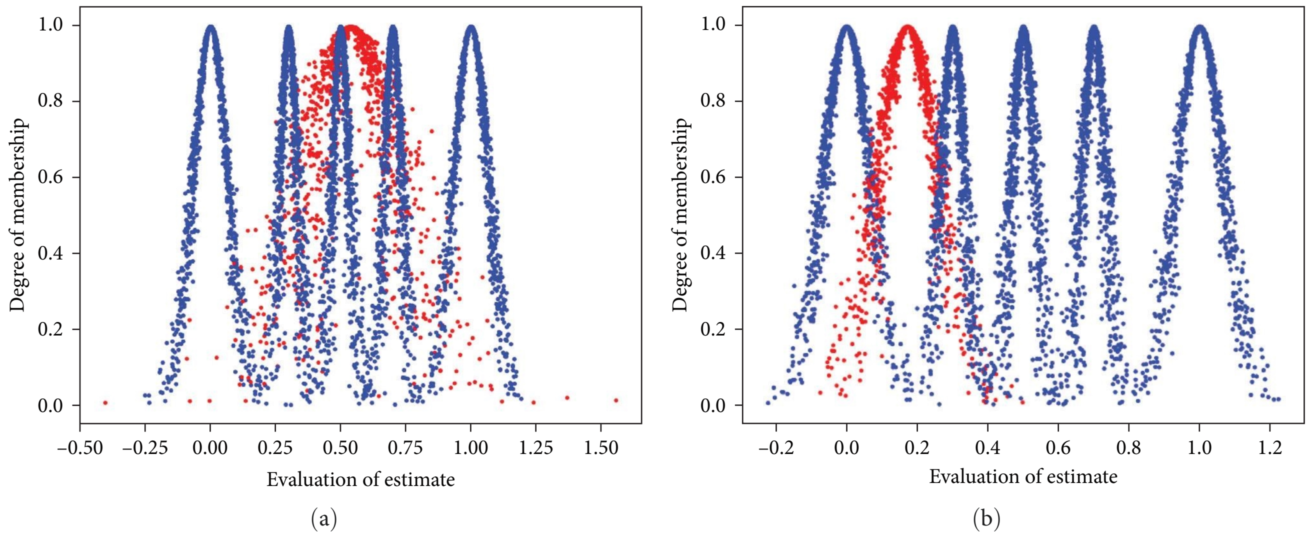


Figure 7: (a) Comparison chart of management factor risk and the evaluation cloud. (b) Comparison chart of construction period factor risk and the evaluation cloud.

As indicated in Figures 6(b) and 8(a), the levels of B2 technology risk and B5 other risks were relatively high. The relatively high level of B2 technology risk was mainly caused by the following issues: the sediment concentration of Jinghe River in the New City section varies significantly with the seasons, with large sediment concentration mainly in the flood season. Moreover, the runoff and sediment of Jinghe River influence the evolution of the Jinghe River channel, prevention and control of urban flood, and construction of water surface and landscapes. Meanwhile, its land use is mainly arable land, forest, and field. The applications, research, arrangement, popularity, and innovation of Jinghe River culture bring about revised risks in engineering design on many occasions, and the construction machines, tools, and equipment are unable to cope with the complicated site environment, which also increases the risk value of the cross-operation. The main reasons for the relatively high level of B5 other risks are derived from policies and laws, economic risks, and natural disaster risks: the approval from relevant departments of hydraulic engineering at each level is not obtained promptly in the early stages of the project, high attention has been paid to ecological conservation from the country, and there are policies and situation of advocating nature and ecology as well as avoiding the excessive building of water landscapes and occupation of arable land, which have influences on the project. Besides, the increasing cost resulting from changes in the market economy and transformation of the supply–demand relationship of construction materials and inflation presents a certain deviation from expectation in the process of construction. In addition, natural disasters including flood and sediment in Jinghe River cause damage to the project construction owing to its runoff

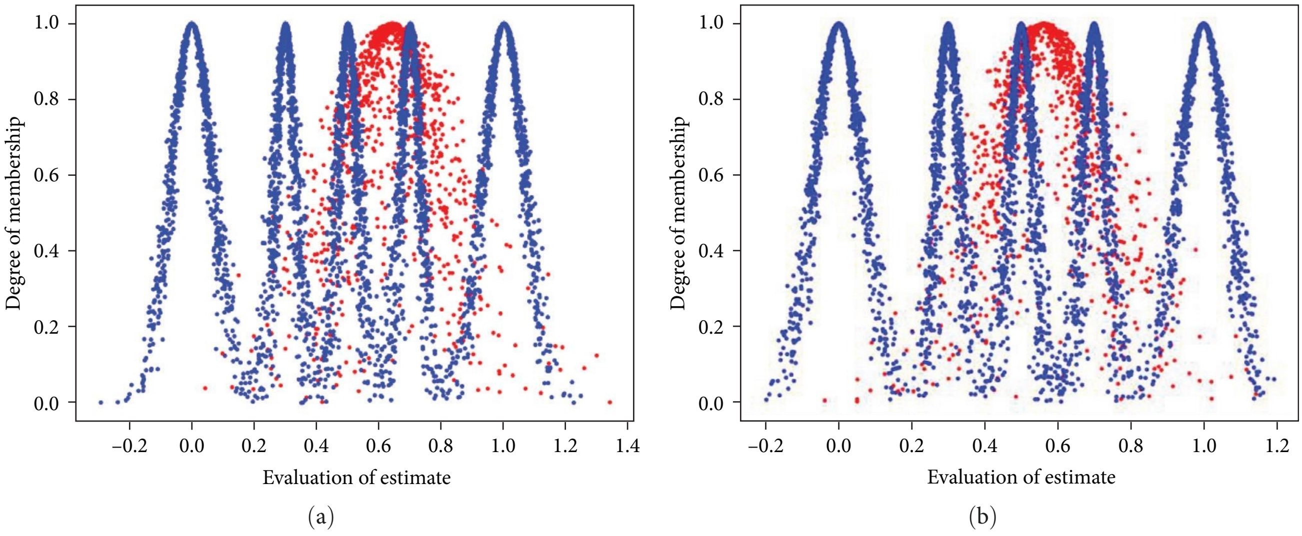


Figure 8: (a) Comparison chart of other factors risk and the evaluation cloud. (b) Comparison chart of comprehensive cloud and the evaluation cloud.

changes with rainfall, uneven distribution within the year, and great changes between years because the river is a rain-source river. The conclusion is consistent with the actual situation of the project construction at the current stage through comparison and research.

5. Discussion

Risk control depends on risk identification and risk assessment. After risks have been identified and assessed, risk avoidance strategies are formulated, and effective risk control means are also implemented. This section identifies and assesses the risks associated with the Jinghe management project. The project's overall risk is medium. B2 technical risks and B5 other risks were also determined to be highly impactful risk factors. Therefore, these risk factors must be controlled prior to a project commencing to reduce their adverse impacts on the project.

Addressing B2 technical risks requires paying attention to construction technology and standards as these are currently not sufficient for the construction required for the Jinghe ecological management project. The construction unit and its construction personnel are required to have the corresponding qualification. Furthermore, the professional and technical personnel and construction technicians' delivering require that the construction unit sufficiently understand new construction technologies and components. During the construction process, the construction unit and the contractor should promptly communicate with each other to solve risks on the construction site as they arise.

The economic risk significantly affects a project. Economic risk can prevent a project from being completed within the specified construction period with the desired quality. The delays and quality issues can result in considerable losses. Two specific measures can be taken to address the economic risk in the Jinghe ecological management project. First, the city's current financial situation should be assessed to ensure the project's cost does not exceed the amount the government can afford. Second, the project's financing channels and sources of investment should be diversified.

Jinghe ecological management project is a government project. Potential adverse effects from government policies can be avoided in two ways. First, project leaders should familiarize themselves with laws and regulations and the government's macrocontrol policies in advance of the project's implementation. Second, prior to predicting policy and regulatory risks, they should be alert to potential risks so as to develop the detailed risk response plans. Project leaders should take various precautionary measures to minimize the probability of problems occurring and the consequences of failures.

The hydrological conditions of the Jinghe have significantly impact the Jinghe ecological management project. Therefore, measures must be taken in advance to avoid natural disaster risks. A flood control management plan should be prepared. Weather conditions should be forecast. Flood conditions should be observed in time to allow for flood control measures. Construction should be speed up to ensure the project is completed before the flood season.

The innovation of the urban river ecological management project risk assessment based on the cloud model includes several aspects: applications of the cloud model, the cloud model is a fuzzy mathematical method that combines subjective and objective evaluations. It can fully consider the uncertainty and fuzziness in the evaluation process, providing more comprehensive and accurate assessment results. In urban river ecological management projects, risk assessments often involve many uncertain factors. The application of a cloud model can better reflect this uncertainty and provide a scientific basis for project decision-making. Multi-index evaluation: the risk assessment of urban river ecological management projects based on the cloud model can comprehensively consider multiple evaluation indicators. Traditional risk assessment methods often focus on one or a few indicators, making it challenging to assess project risks comprehensively.

However, the evaluation method based on the cloud model can integrate multiple indicators for a comprehensive evaluation, thus revealing the diversity and comprehensiveness of project risks more comprehensively. Uncertainty handling: the risk assessments in urban river ecological management projects often face a large amount of uncertainty, such as data gaps and expert subjectivity. The evaluation method based on the cloud model can effectively handle these uncertainties by introducing cloud generation, cloud inference, and other techniques. Compared to traditional evaluation methods, the cloud model-based approach can better reflect uncertainty and provide reliable assessment results. Visual presentation: the innovation of the risk assessment of urban river ecological management projects based on cloud models can include visual presentation methods. By presenting assessment results in the form of charts, maps, and other visual representations, the results can be conveyed more intuitively to decision-makers and stakeholders. This visual presentation not only enhances the effectiveness of information communication but also makes it easier for decision-makers to understand. Besides, it also compares the risk levels of different project options, and facilitates better decision-making and management strategies. Compared with existing research, this study focuses on the fuzziness and randomness in the risk assessment process of urban river ecological management projects. With the advantages of a multilevel fuzzy comprehensive evaluation model, the study addresses the shortcomings of the multilevel fuzzy comprehensive evaluation by introducing and improving upon cloud model theory. As a result, a cloud model-based multilevel fuzzy comprehensive evaluation model for urban river ecological management projects is developed. The model has been improved from three aspects: comment set cloud model, cloud model scale, and membership degree cloud model. These improvements significantly reduce the subjectivity of the research results. In summary, the research focuses on applying cloud models, multi-index evaluation, uncertainty handling, and visual presentation. These innovations make the assessment more comprehensive, accurate, and scientific, providing critical support and guidance for decision-making and management of urban river ecological management projects.

6. Conclusion

Urban river ecological management projects affect people's lives and property, national economic development, social progress, and stability. They also involve multilevel systems engineering. Risk evaluation is critical for the urban river ecological management projects. This paper is a case study of the risks affecting the Jinghe ecological management project. This paper aims to analyze engineering risks to reduce the occurrence of engineering setbacks and thus ensure that the project optimizes the Jinghe River's ecological environment. Properly developing the Jinghe River would improve people's lives. Additionally, the research results can improve the risk management awareness and ability of participants in future urban river ecological management projects.

Because of the fuzziness and difficulty in the quantization of urban river management project risks, the risk evaluation method of fuzzy comprehensive evaluation based on the cloud model theory was proposed in this paper. First, the evaluation indicator system, which can comprehensively reflect river management risks, was established, including five second-level indicators and 23 third-level indicators, by risk investigation and research of the urban river ecological management project. Second, AHP was adopted to determine the weight of each indicator. Last, the urban river ecological management risk evaluation cloud model based on the cloud model has been constructed. The example calculation yields an overall risk level for the Jinghe ecological management project at the higher risk range. This conclusion is consistent with the project's actual risk at its current stage. Additionally, the project's risk levels for B2 technical risks and B5 other risks are high. The measures to control these two kinds of risks should be strengthened. The case study confirms the validity and practical applicability of the improved fuzzy comprehensive evaluation method based on the cloud model.

In the improved fuzzy comprehensive evaluation method for urban river ecological management projects based on the cloud model, this study has chosen the standard cloud model as the foundation. The improvements are proposed in three aspects: comment set cloud model, fuzzy relation matrix improved with the cloud model, and improved fuzzy synthesis algorithm for the cloud model. Future research needs to explore and study how to select different forms of cloud models for indicators in different states.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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