

Risk Assessment and Management in Water Resources Projects: Insights and Future Directions

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Abstract. Because of the unique uncertainty and social service of water conservancy projects, it is particularly important to study the risk of such projects. This paper analyzes the documents related to the risk of water conservancy projects in recent years and finds that LEC, AHP, FAHP, combination weighting, and machine learning are most widely used in risk assessment and risk management. Firstly, this paper briefly introduces and evaluates these methods, analyzes what kind of situation they are suitable for and their advantages and disadvantages. Then, the main risk studies in recent years are divided into two categories: risk assessment and risk management, and the assessment part is divided into construction risk, social stability risk and ecological risk according to the type of risk. Likewise, in the management part, the risks are divided into construction and financial risks. Finally, it can be found that modern scholars have studied AHP and FAHP more deeply and applied more, but the use of machine learning is the least, and the risk assessment management of the whole project is more concentrated in the construction stage. This paper aims to use these research gaps to provide ideas for future risk research of water conservancy projects so that the operation of water conservancy projects is more stable, which is the practical significance of this article.

Keywords: Risk assessment; Risk management; Water conservancy project.

1. Introduction

The water conservancy project is special and has different characteristics from other general projects. Generally, the buildings of the water conservancy project are closely related to the water and are on medium and large scale. The site selection and operating conditions of the building are closely related to the climate. These features determine the uncertainty of water conservancy projects. At the same time, water conservancy projects can control water resources, so they play an important role in environmental protection and balancing the ecosystem, which has huge social benefits. In this way, the risk research of water conservancy project is a topic of wide concern, which has practical significance.

From the research in recent years, it can be found that scholars' research on risk is more and more detailed. In the early years, scholars paid attention to the LEC method. This method is mainly based on subjective judgment, which needs to judge the LIKELIHOOD of a dangerous environment, the frequency of staff EXPOSURE to a dangerous environment and the possible CONSEQUENCES of the accident. After multiplication, the risk index DANGER can be obtained, where the higher the D value, the greater the project risk [1]. However, this method is very subjective, so the research direction of this method has gradually shifted to how to improve it. After that, scholars began to study the use of the AHP method generally, that is, expert scoring, to establish a judgment matrix to calculate the weight of each risk factor and establish the weight matrix shown below [2].

$$W = [W_1, W_2, \dots, W_n]^T \quad (1)$$

The greater the weight of the risk factor in the matrix, the worthier of attention. The disadvantage of this method is that it could be more objective, so some scholars have improved it. The improved method is similar to AHP. The difference is that FAHP needs to establish the triangular fuzzy number of each index after establishing the weight matrix and then calculate the weight value of the fuzzy

vector [3]. Given the above characteristics, the improved FAHP method is widely used in various fields.

Taking the research of Liu and other scholars as an example, researchers also explored the combination weighting method. Essentially, this method combines AHP and the entropy weight method. The entropy weight method is a purely objective evaluation method based on the degree of deviation of each index to determine its weight, so the disadvantage is that it cannot reflect the difference in decision-makers' attention to different indicators.

Machine learning is one of the most popular algorithms today, and some scholars have applied it to the risk research field of water conservancy projects. For example, the Apriori algorithm finds the correlation between each index through the frequent search in the data set and then uses this association as a new operation rule [4].

When the support of a search is lower than the minimum support, the search can be stopped. Another way is known as the ANNs, which takes the organism's nervous system as a sample and combines various factors with hierarchical relationships to form a network structure in which the signal transmission is replaced by mathematical expression. In a complete neural network, input, hidden layer, and output should exist. The hidden layers need an activation function to unify their expressions.

This research focuses on the five common analysis methods, expounds on their pros and cons, and analyzes the risk research in recent years according to the risk categories. This study aims to find out the gaps in the risk research of water conservancy projects in China and to evaluate the use scenarios of several methods to determine the future research direction so that the water conservancy projects can be used more stably.

2. Common Assessment and Management Methods

2.1. LEC Method

What is clear is that this approach is highly subjective, which means the primary and secondary distinction of risk factors have a great relationship with people and the environment. In this way, there is much room for improvement.

A researcher introduced the safety management compensation factor and the control measure state factor based on the LEC method and obtained the new formula of the LEC method. To a certain extent, it makes up for the defect that the original method does not consider the safety control measures and cannot evaluate the risk of the project as a whole [5]. The improved formula is as follows:

$$D = f \times m \times L \times E \times C \quad (2)$$

According to the presence or absence of security agencies and full-time security administrators, f is divided into 5 levels, as shown in Table 1; according to the presence or absence of safety education and control measures, m is divided into 4 levels, as shown in Table 2.

Table 1. The value of safety management compensation factor f

f	Safety management agency	Full-time safety management personnel	Be on duty or not	Safety record
1.3	Neither of them		\	\
1.2	One of the two		\	\
1.1	Both		Yes	No
1.0	Both		Yes	Insufficient
0.9	Both		Yes	In detail

Table 2. The determination method of control measures state factor m

m	safety education	emergency measure	preventive measure
1	No	No	No
0.8	Yes	No	No
0.6	Yes	Yes	No
0.2	Yes	\	Yes

The study indicated that the improved LEC method could reduce the subjective interference in the original method. However, this method relies heavily on the experience of experts, so it has great limitations and needs to be modified according to the actual situation. In this way, it has yet to be widely used.

2.2. Analytic Hierarchy Process

As mentioned in the introduction, a judgment matrix is needed to calculate the weight of each risk factor. Usually, it is necessary to test the consistency of the judgment matrix to ensure that the evaluation is scientific and effective.

However, after analyzing the calculation process of this method, it is found that AHP is only suitable for the case of fewer factors and less data information. Similar to the LEC method, the formation of the judgment matrix is based on expert evaluation, which is still subjective and unconvincing. Also, the factors are not independent of each other, and the judgment matrix needs to be updated at any time, so the judgment result of a certain time is unstable.

2.3. Fuzzy Analytic Hierarchy Process

Based on the AHP method, the newly introduced weight vector W and the new fuzzy matrix F are calculated using formula (2) to obtain a comprehensive evaluation result $for Z$.

$$Z = W \times F \quad (3)$$

These parameters improve the subjective problems of the above traditional analytic hierarchy process, can solve more complex problems, and improve the reliability of project decision-making.

Taking an irrigation project, for example, Zhu used the FAHP method to establish a risk evaluation index system and then comprehensively evaluated the potential risks faced by the project [6]. This study illustrates another advantage of FAHP: that is, the researcher can use the fuzzy characteristic of the method itself to reflect the more real opinions of the decision-makers and establish the connection between the various nodes to form a scientific and effective evaluation of a project. This is also an important reason why FAHP is widely used in evaluating the risk of water conservancy projects.

2.4. Combination Weighting Method

A direct combination of AHP and entropy weight method by matrix multiplication will lead to a serious imbalance in weight distribution. This method can avoid such problems. Liu identified 16 influencing factors, used AHP to establish a judgment matrix, calculated the expert's score of these 16 factors, and then used the entropy weight method to calculate the weight of each influencing factor [7].

By comparing the weights of each factor obtained by the AHP method, the entropy weight method and the combination weighting method in the calculation, it can be found that the values obtained by the combination weighting method are often located between the first two values, which shows that the method avoids being too objective or subjective.

2.5. Machine Learning Method

2.5.1 Apriori algorithm

Taking 186 accidents in three water conservancy projects in the mainstream of the Yangtze River as an example, Sun Kaichang used this algorithm to determine the relationship between the key factors leading to water conservancy project accidents and provided data support for the emergency plan in the project [8]. After data mining, it is found that the safety education of construction personnel is the key to effectively solving other risk factors. It has a great relationship with the risk factor system of the whole water conservancy project. Also, there is a potential connection between the quality of construction personnel and safety production education, so these two factors are the focus of the next need to be addressed.

However, it can also be seen from the process of this algorithm that this method could be more efficient when the database is large, and the data type is large.

2.5.2 Artificial neural network

This method also has some defects. It requires data to train this algorithm, and this shortcoming will become a major obstacle when there is a large amount of data collection or storage. Also, training this algorithm will consume much time and be more difficult for situations requiring rapid or real-time application [9].

3. Risk Assessment

3.1. Project Construction Risk assessment

Generally, the risks in engineering are mainly composed of five factors: human, machine, material, law and environment, and their existence may affect each other. Wang Tie used the AHP method to design the optimal project risk management scheme based on several indexes. Firstly, as shown in Table 3, according to the characteristics of the water conservancy project itself, Wang Tie classified risks by level [10].

Table 3. Risk classification of water conservancy project construction

Risk assessment	Criterion layer B	First-level indicators C
	Inherent risk B1	Natural risk C1
	Specific risk B2	Owner risk C2
		Contractor risk C3
	Human risk B3	Design risk C4
		Consulting supervision risk C5

Next, experts are invited to assign scores to the relative importance of each factor, and a judgment matrix is established. The ranking results are shown in Table 4.

Table 4. Total ordering of elements

CRITERION LAYER	FIRST-LEVEL INDICATORS
B1 (0.5268)	C1 (0.1201)
B2 (0.1406)	C2 (0.2216)
B3 (0.3326)	C3 (0.3052)
CR = 0.0461	C4 (0.1981)
	C5 (0.1550)
	CR = 0.0576

Table 5 tests whether the judgment matrix satisfies the average, random, and consistency principle. $ICR < 0.10$, the matrix meets the requirements. Otherwise, it needs to be re-adjusted until the inequality is satisfied.

From the above results, it can be seen that the project's inherent risk is the biggest source. In addition, the possible impact of human errors should also be considered. Meanwhile, the construction team should also strengthen the control of the contractor and the owner to reduce the risks arising from both.

3.2. Social Stability Risk Assessment

In the process of national economic development, the water conservancy project, as an infrastructure, brings a good living environment for human beings. It is an important measure to benefit humanity and has great social benefits [11]. Generally, the risk system is shown in Table 5.

Table 5. Social stability risk factor's hierarchical structure

Social stability risks	First-level	Second-level
	Policy planning and approval	Development and special planning
		Project approval procedures
		Public participation
	Land acquisition and resettlement	Resettlement scheme
		Land compensation standard
		Land compensation funds
		Information disclosure
		Production and living level
		Late support
	Technical economy	Project site selection and layout
		Design of the hydro project
		Resource and benefit distribution
	Ecological condition	Environmental pollution
		Ecological damage
		Resource plunder and loss
	Construction, operation and management	Organization management
		Quality management
		Construction impact
	Social environment and public opinion	Religions and customs
		Public safety
		Media public opinion

Li and other scholars use various methods to evaluate the social stability risk of major water conservancy projects and compare the advantages and disadvantages of each method. It is found that simple qualitative or quantitative evaluation methods need strong operability [12].

Ma used FAHP as the foundation to conduct a more in-depth assessment, combined with the traditional entropy weight method in different ways [13]. The author analyzed and compared the weights obtained by original and improved methods to obtain a similarity matrix. From the matrix, the improved methods have high similarity, indicating that they are more applicable. Furthermore, it can be seen from the results that the most influential factors are the resettlement scheme of immigrants and the plunder and loss of resources, indicating the improving points.

3.3. Ecological risk assessment

According to Section 2.2, the ecological risk of a water conservancy project is an important risk factor. Water conservancy projects impact the hydrological situation near the project, the resource development of upstream and downstream basins, aquatic organisms and wetland situations [14]. In 2017, Song and other scholars constructed a model for ecological risk assessment, qualitatively and

quantitatively analyzing ecological risks and supporting hydropower resource development and planning.

The ecological risk assessment of water conservancy projects is an interdisciplinary analysis combining hydrology, biology and data analysis, which is used to solve practical engineering problems effectively and is also conducive to the sustainable development of the water conservancy industry [15]. In this study, Song used the following formula to characterize the impact of ecological risk:

$$R = q \times h \quad (4)$$

Among them, R is the risk degree of water conservancy project construction; q is the influence degree of water conservancy project construction, which indicates the probability of accident occurrence; h is the sensitivity of the ecosystem risk source bearing body, which indicates the loss and harm of the ecosystem after the accident.

Likewise, the author divided the ecological risk into several hierarchical indicators shown in Table 6, established the risk assessment matrix cap A, and calculated the weight vector R .

Table 6. Ecological risk assessment system

Ecological risk assessment	First-level	Second-level
	Aquatic ecosystem	Dam barrier
		Hydrological environment
	Terrestrial ecosystem	Reservoir inundation
	Social system	Human factors

It can be concluded that the risk value of a risk factor is

$$AX = W(A \cdot X) \quad (5)$$

Among them, Represents the weight value of a risk factor. According to this value, the optimal engineering scheme is selected to minimize the harm caused by water conservancy projects to the ecological environment.

4. Risk Management

4.1. Project Construction

In the construction process of a water conservancy project, the process used, the project's procedure, and the construction environment's complexity are all uncertain factors affecting a project. If these factors are not scientifically managed, it will increase the possibility of risks in the construction process to a certain extent [16]. Following the AHP method, Liang Mo and his partner divided a project into a construction operation area, material storage area and living office area according to the area. They established a common risk index system in each area.

Through discussion, it is found that the implementation of government supervision is not in place, the risk management awareness of the five parties of water conservancy projects (design, establishment, construction, construction, investigation) is relatively weak, and the treatment methods after the occurrence of risk accidents are relatively backward. Given these directions, the construction project can take corresponding remedial measures to solve the safety problems in the construction process in time.

4.2. Project Financial

The water conservancy project generally involves social, economic, and ecological benefits. Given its ability to control and utilize water resources, water conservancy projects can generate economic benefits by forming related aquatic products. However, a large amount of funds is needed, so rational allocation is important in ensuring the project's economic benefits [11].

The water conservancy project is large in scale and complicated in procedure. Its bidding and procurement are always the focus of the government, as well as the focus of project cost control and fund management. Ni focused on bidding and procurement and established a risk index system, including bidding planning, design depth, design and technical scheme change, bid estimate, contract risk and some force majeure [17]. The bidding procurement risk control matrix is established according to each risk's influence degree and controllability.

This method succeeds in visualizing risk management decision-making. However, it still has great limitations: it is as subjective as AHP, and the position of each risk in the matrix is determined by mutual comparison. It is impossible to obtain its importance-related value through data processing.

5. Conclusion

The following conclusions are obtained after analyzing five risk assessment and management methods (LEC, AHP, FAHP, combination weighting, and two of the machine learning methods) and analyzing relevant research cases.

The current research is mostly related to the project's construction process risks. Many links affect the water conservancy project, including design, establishment, etc., but there are few risk studies in these two aspects.

The methods are mostly AHP or FAHP, and there needs to be more research on machine learning methods, but machine algorithm is a hot spot today and is more convenient than other manual methods, which can be studied in depth.

The ecological risk assessment and management of water conservancy projects are not systematic, and it is necessary to establish a separate evaluation system.

It has been relatively mature in risk identification and risk assessment. Still, there needs to be more relevant research on managing various risks, which means the focus of risk research can be placed on risk management.

References

- [1] Jin Liwen, Zheng Jia. Application of the LEC method in scientific research projects' research and development process. *Chemical Production and Technology*, 2021, 27(04): 42-45+10.
- [2] Sun Yinxing. Discussion on risk management of water conservancy project based on a hierarchical analysis method. *Journal of Guangdong Water Conservancy and Electric Power Vocational and Technical College*, 2023, 21(02): 45-48.
- [3] Mistarihi Z M, Magableh M G. Prioritization of Supply Chain Capabilities Using the FAHP Technique. *Sustainability*, 2023, 15(7).
- [4] Jumaili A A H A, Muniyandi C R, Hasan K M, et al. Intelligent transmission line fault diagnosis using the Apriori-associated rule algorithm under a cloud computing environment. *Journal of Autonomous Intelligence*, 2023, 6(1).
- [5] Yang Kai, Lv Feng. Research on safety risk evaluation of water conservancy projects based on improved LEC. *Sichuan Water Resources*, 2023, 44(01): 146-148+152.
- [6] Zhu Weiwei. Research on risk assessment and control of water conservancy project construction based on fuzzy hierarchical analysis. *Pearl River Water Transport*, 2022(21): 114-116.
- [7] Liu Xiaofeng, Li Yunbo, Dong Yong. Comprehensive evaluation and application of water conservancy project duration risk based on combination assignment. *Water Resources Science and Cold Region Engineering*, 2023, 6(02): 146-148.
- [8] Sun Kaichang, Feng Jiwei. Relationship analysis of water conservancy project risk factors under machine learning algorithm. *Hydropower*, 2022, 48(01): 91-93+117.
- [9] Hussain T M, Sarwar A, Tariq M, et al. An Evaluation of ANN Algorithm Performance for MPPT Energy Harvesting in Solar PV Systems. *Sustainability*, 2023, 15(14).

- [10] Tie Wang. Risk assessment based on water conservancy engineering construction project. Heilongjiang Water Resources Science and Technology, 2019, 47(04): 200-203.
- [11] Liu AH, Chu TF, Huang J. Exploration on strengthening social and economic benefits of water conservancy project. China Equipment Engineering, 2021, (07): 236-237.
- [12] Li Jingjing, Hua Jian. An overview of social stability risk assessment of major water conservancy projects. Water Resources Economy, 2016, 34(04): 4-8+73.
- [13] Ma Shengcheng. Research on social stability risk evaluation of water conservancy project based on FAHP and entropy right. North China University of Water Conservancy and Hydropower, 2018.
- [14] Chen Jiyu. An overview of the impact of water conservancy project construction on the ecological environment under the new situation. Water Safety, 2023(05): 89-91.
- [15] Song Jingfeng. Exploration of ecological risk assessment model for water conservancy project construction. Water Resources Development and Management, 2017(01): 52-54+45.
- [16] Liang Mo. Construction risk management analysis of water conservancy project construction. Engineering and Construction, 2023, 37(03): 1053-1055.
- [17] Ni Jinsheng. Risk management analysis of water conservancy project bidding and procurement. China Logistics and Purchasing, 2019, (13): 44-46.