ISSN 2616-5902 Vol. 6, Issue 2: 235-242, DOI: 10.25236/AJBM.2024.060234

Risk Assessment of Water Saving Management Contract Based on Normal Cloud Model

Fan Yang[1,a,*], Xinlu Lu[1,b]

[1]School of Management Engineering and Business, Hebei University of Engineering, Handan, China
[a]yangfan_220401@163.com, [b]xinlulu0401@163.com
[*]Corresponding author

Abstract: *The Water Saving Management Contract (WSMC) is the novel market-oriented water-saving service model specifically designed for water conservation. It uniquely shifts the risk burden away from water users to water-saving service providers, making risk assessment a pivotal consideration for project participants in devising investment strategies. Drawing upon cloud models that reconcile qualitative and quantitative uncertainties, this paper proposes a risk assessment model for WSMC grounded in a generalized cloud model framework. Firstly, a comprehensive evaluation system integrating qualitative and quantitative indicators is established. Weights are determined using a combination weighting method based on the Analytic Hierarchy Process (AHP) and entropy weight method. Secondly, the standard cloud model is constructed based on standard level division. Evaluation indicators are then scored based on historical literature, expert opinions, and project-specific implementation conditions to formulate a comprehensive evaluation cloud model. Finally, through case validation, the findings are presented using cloud diagrams to confirm the model's feasibility.*

Keywords: *Water Saving Management Contract; Risk Analysis; Normal Cloud Model; Combination Weighting Method*

1. Introduction

Water is fundamental to life, essential for production, and crucial for ecological balance. Currently, the global community faces a complex array of water resource challenges, including rapid increases in water demand, water scarcity, water pollution, and ecological degradation [1-3]. Particularly in developing countries, these water resource issues have severe negative impacts, hindering economic development and posing threats to both national security and human survival [4]. Therefore, urgent action is required to implement effective water-saving measures to address the pressing issues surrounding water resources.

In response to the evolving water management policies of the modern era and to advance water-saving strategies, China's Ministry of Water Resources has introduced an innovative water management model known as WSMC [5]. WSMC involves contractual agreements between water-saving service enterprises and water users. Under these contracts, service enterprises secure capital for water user projects, integrate cutting-edge technologies, and provide services such as water-saving transformations and management. This enables the sharing of water-saving benefits, allowing for the recovery of investments and the generation of profits [6]. A defining feature of WSMC projects is that water users engage in water-saving technology transformations with minimal risk and net benefits, while water-saving service companies assume higher levels of risk [7]. Consequently, conducting rigorous risk assessments is crucial for all stakeholders involved in WSMC projects to formulate effective investment strategies.

Ma [8] and Li [9] have conducted thorough investigations into the risks associated with WSMC projects, proposing robust mitigation strategies. It is noteworthy that contract water conservation management is still in its preliminary stages within China, leading to a scarcity of research on associated risks. However, leveraging insights from analogous projects can provide invaluable perspectives and strategies for risk management in this nascent field.

Wang et al. contributed to the theory and practice of risk management in international engineering, procurement, and construction delivery by establishing interdisciplinary connections between risk management, cooperation, and contractor capabilities [10]. Yang et al. measured risk management in Energy Performance Contract (EPC) projects from a game-theoretic perspective [11]. Jokar utilized a fuzzy multi-criteria decision-making method to assess and rank risks in Public-Private Partnership (PPP)

ISSN 2616-5902 Vol. 6, Issue 2: 235-242, DOI: 10.25236/AJBM.2024.060234

projects [12]. Noorzai conducted an evaluation of risks in PPP within conflict-prone areas and proposed corresponding solutions [13]. AL-Aga conducted risk analysis on Build-Operate-Transfer (BOT) projects using the AHP [14]. Patel employed a fuzzy probability method to assess risks in Indian BOT toll roads [15].

Through the review, we have found that the current methods of risk assessment primarily focus on qualitative analysis [16-19]. However, the WSMC is characterized by significant complexity, ambiguity, and randomness. However, these methods often emphasize qualitative descriptions, overlooking these characteristics in the evaluation process.

The normal cloud model effectively bridges the gap between qualitative and quantitative uncertainties in objective phenomena. It addresses uncertainties such as fuzziness and randomness inherent in assessment systems [20-22]. Based on this, we propose a combined weighting-normal cloud evaluation method to quantify the risks in WSMC, providing valuable insights for project implementation.

The paper is structured as follows: The Section 1 serves as the introduction., followed by the model construction in the Section 2. The Section 3 comprises case analysis, while the Section 4 concludes the study.

2. Methodology

This section elaborates on the quantification of risk issues encountered within WSMC through the application of a synthesized weighting-normal cloud approach, culminating in the development of an innovative risk assessment framework as depicted in the technical roadmap. Initially, risk evaluation metrics are delineated and classified by reviewing scholarly literature and integrating real-world scenarios. Subsequently, a hybrid weighting methodology that amalgamates the AHP and the entropy weight method is employed to ascertain the weights of the evaluation metrics. Thereafter, the numerical characteristics of the composite evaluation cloud are derived utilizing the normal cloud model.

2.1. Construction of Risk Assessment Indicator System

In order to assess the risks associated with WSMC, we integrate previous research on the risks of WSMC, draws on the identification results of risks in EPC, and considers potential risks from other projects. Five primary risk assessment indicators including finance risk, operational risk, market risk, policy risk, and benefit risk are selected, along with 18 secondary indicators. This establishes a structured framework for conducting risk assessments in WSMC project, depicted in the accompanying Figure 1.

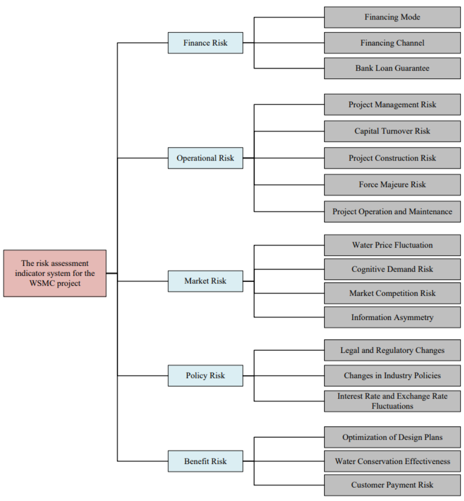

Figure 1: The risk assessment indicator system for the WSMC project.

2.2. Determining the Weight of Indicators

The determination of indicator weights mainly involves two methods: subjective weighting and objective weighting. Subjective weighting is simple to operate and does not require a large amount of data. However, the evaluation process relies on the personal preferences, knowledge, experience, and subjective views of experts and scholars, resulting in biased results. Objective weighting mainly

ISSN 2616-5902 Vol. 6, Issue 2: 235-242, DOI: 10.25236/AJBM.2024.060234

calculates weights from the analysis of the relationships between sample data, providing an objective perspective to avoid subjective judgments. However, it may deviate from the actual meaning of indicators due to information asymmetry, greatly compromising the scientific validity of the evaluation results.

Hence, this study employs a hybrid approach combining the AHP and the entropy weight method to determine weights. By integrating expert opinions and actual monitoring data, this method minimizes the impact of subjective biases, thereby enhancing accuracy. The principal technique involves augmenting the weights of both subjective and objective factors, as outlined in Formula 1.

$$\omega_i = \frac{\omega_i' \cdot \omega_j}{\sum_{i=1}^{n} \omega_i' \cdot \omega_j} \quad (1)$$

which, ω_i denotes the comprehensive weight, ω_i' denotes the weights determined by AHP, ω_j denotes the weights determined by the entropy weight method.

2.3. Construction of WSMC Risk Assessment Model

2.3.1. Digital Characteristics of Standard Cloud

Based on the risk assessment indicators constructed earlier for contract energy management, we establish the evaluation indicator set Z and the evaluation comment set V. Subsequently, we categorize the comments in V into levels and provide bilateral constraints for the risk assessment levels, where Vmax and Vmin represent the upper and lower limits of the risk assessment levels, respectively. Then, we transform the risk assessment levels in each comment set into numerical characteristics of standard cloud models that can quantify actual risks using the following equation.

$$\begin{cases} Ex = \frac{\text{Vmax}+\text{Vmin}}{2} \\ En = \frac{\text{Vmax}-\text{Vmin}}{6} \\ He = \text{k} \end{cases} \quad (2)$$

In this paper, the evaluation results are divided into five levels: low risk, relatively low risk, moderate risk, relatively high risk, and high risk. We choose the value of k to be 0.1. By using the equation mentioned earlier to transform these risk assessment levels into numerical characteristics of standard cloud models, we obtain the digital characteristics of WSMC as shown in Table 1.

Table 1: Digital Characteristics of WSMC.

Risk Level	Score Range	Standard Cloud Parameters
Low Risk	[0,2)	(1,0.333,0.1)
Relatively Low Risk	[2,4)	(3,0.333,0.1)
Moderate Risk	[4,6)	(5,0.333,0.1)
Relatively High Risk	[6,8)	(7,0.333,0.1)
High Risk	[8,10]	(9.0.333,0.1)

Converted to standard cloud diagram as follows in Figure 2.

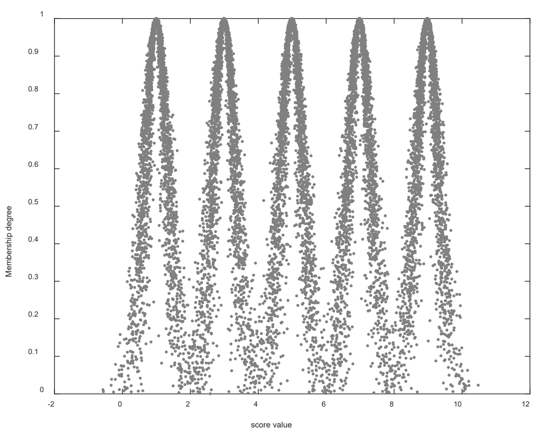

Figure 2: WSMC Risk Assessment Standard Cloud Model.

ISSN 2616-5902 Vol. 6, Issue 2: 235-242, DOI: 10.25236/AJBM.2024.060234

2.3.2. Determining Evaluation Cloud Parameters

Following the establishment of the risk assessment standard cloud, experts and scholars assign scores to each risk assessment factor of the project. Subsequently, the collected data undergoes analysis and organization. This processed data is then inputted into a reverse cloud generator, facilitating its transformation into fundamental cloud parameters. The calculation process unfolds as follows:

(1) Calculate the sample mean Ex.

$$Ex = \bar{X} = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{3}$$

(2) Calculate the sample variance S^2.

$$S^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{X}) \tag{4}$$

(3) Calculate the entropy of cloud droplets En.

$$En = \sqrt{\frac{\pi}{2}\cdot\frac{1}{n}\sum_{i=1}^{n}|x_i - \bar{X}|} \tag{5}$$

(4) Calculate the super-entropy of cloud droplets He.

$$He = \sqrt{|S^2 - En^2|} \tag{6}$$

2.3.3. Evaluate the Cloud Parameters

Based on combined weighting to derive weights, the following formula is used to calculate the basic cloud parameters of evaluation indicators in the criterion layer, yielding parameters for both the criterion and objective layers.

$$\begin{aligned} Ex &= \frac{w_1}{w_1+w_2+\cdots+w_n}Ex_1 + \cdots + \frac{w_n}{w_1+w_2+\cdots+w_n}Ex_n \\ En &= \frac{w_1^2}{w_1^2+w_2^2+\cdots+w_n^2}En_1 + \cdots + \frac{w_n^2}{w_1^2+w_2^2+\cdots+w_n^2}En_n \\ He &= \frac{w_1^2}{w_1^2+w_2^2+\cdots+w_n^2}He_1 + \cdots + \frac{w_n^2}{w_1^2+w_2^2+\cdots+w_n^2}He_n \end{aligned} \tag{7}$$

Due to the substantial intercorrelation among the primary evaluation indicators, a method involving virtual cloud synthesis calculation is utilized to aggregate them, leading to the determination of the numerical characteristics of WSMC.

$$\begin{aligned} Ex &= \frac{Ex_1En_1w_1+Ex_2En_2w_2+\cdots+Ex_nEn_nw_n}{En_1w_1+En_2w_2+\cdots En_nw_n} \\ En &= En_1w_1 + En_2w_2 + \cdots En_nw_n \\ He &= \frac{He_1En_1w_1+He_2En_2w_2+\cdots+He_nEn_nw_n}{En_1w_1+En_2w_2+En_nw_n} \end{aligned} \tag{8}$$

3. Case Study Analysis

For the WSMC project between GT and the university in Hebei Province, a rigorous analysis and computation will be undertaken to validate the feasibility of the model.

3.1. Determination of Indicator Weights

The combined weighting results based on AHP-Entropy Method are as follows in Table 2.

Table 2: Weight of Risk Assessment Indicators for WSMC.

Primary Indicator	Combined Weight	Secondary Indicator	Combined Weight
Finance Risk	0.0431	Financing Mode	0.0197
		Financing Channel	0.0362
		Bank Loan Guarantee	0.0063
Operational Risk	0.4345	Project Management Risk	0.1725

ISSN 2616-5902 Vol. 6, Issue 2: 235-242, DOI: 10.25236/AJBM.2024.060234

		Capital Turnover Risk	0.0286
		Project Construction Risk	0.0612
		Force Majeure Risk	0.0505
		Project Operation and Maintenance	0.0556
Market Risk	0.3773	Water Price Fluctuation	0.0453
		Cognitive Demand Risk	0.1848
		Market Competition Risk	0.1168
		Information Asymmetry	0.0337
Policy Risk	0.0385	Legal and Regulatory Changes	0.0245
		Changes in Industry Policies	0.0081
		Interest Rate and Exchange Rate Fluctuations	0.0193
Benefit Risk	0.1066	Optimization of Design Plans	0.0697
		Water Conservation Effectiveness	0.0524
		Customer Payment Risk	0.0149

3.2. Comprehensive Performance Evaluation Results

Utilizing the expert scoring method, the risk indicators of WSMC were evaluated and scored. These scores were then transformed into cloud model characteristic values for each indicator using a reverse cloud generator. The parameters of the secondary indicator cloud model, combined with their respective weights, were processed to derive the cloud model parameters for each primary indicator, as presented in *Table 3*.

Table 3: WSMC Risk Indicator Cloud Parameters.

Primary Indicator	Cloud Model Parameters	Secondary Indicator	Cloud Model Parameters
Finance Risk	(3.9563,1.4368,0.5794)	Financing Mode	(2.6,1.2.32,0.3903)
		Financing Channel	(5,1.5040,0.6362)
		Bank Loan Guarantee	(2.2,1.5040,0.5535)
Operational Risk	(6.1546,1.3886,0.5636)	Project Management Risk	(7.2,1.3536,0.5879))
		Capital Turnover Risk	(6.8,1.3536,0.5879)
		Project Construction Risk	(5.6,1.4037,0.3849)
		Force Majeure Risk	(2.4,1.4037,0.3849)
		Project Operation and Maintenance	(6.6,1.7045,0.6873)
Market Risk	(5.2130,1.5654,0.5351)	Water Price Fluctuation	(3,1.0027,0.8789)
		Cognitive Demand Risk	(5.8,1.5040,0.5535)
		Market Competition Risk	(4.8,1.8048,0.4365)
		Information Asymmetry	(6.4,1.5541,0.5439)
Policy Risk	(3.0686,1.4783,0.6048)	Legal and Regulatory Changes	(2.2,1.2032,0.6172)
		Changes in Industry Policies	(3,1.0027,0.8789)
		Interest Rate and Exchange Rate Fluctuations	(4.2,2.0053,0.5366)
Benefit Risk	(6.7347,1.4583,0.5671)	Optimization of Design Plans	(6.2,1.5040,0.5535)
		Water Conservation Effectiveness	(7.2,1.3536,0.5879)
		Customer Payment Risk	(7.6,1.7546,0.6063)

Based on this, the cloud diagram is illustrated as follows:

ISSN 2616-5902 Vol. 6, Issue 2: 235-242, DOI: 10.25236/AJBM.2024.060234

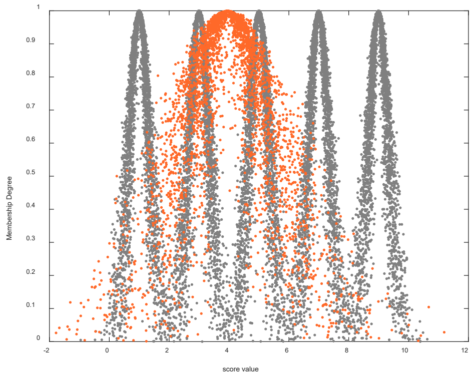

Figure 3

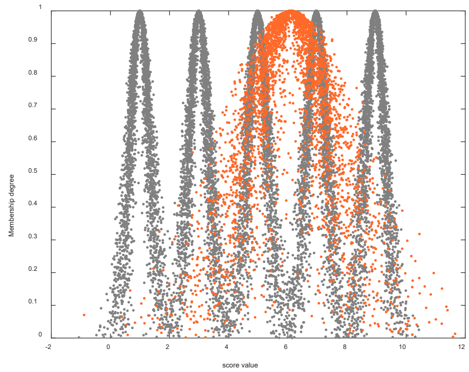

Figure 4

Figure 3: Cloud Diagram of Finance Risk Assessment

Figure 4 Cloud Diagram of Operational Risk Assessment

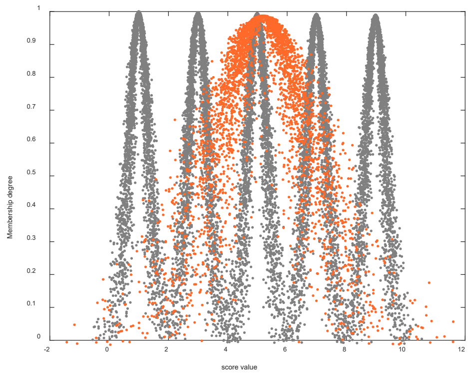

Figure 5

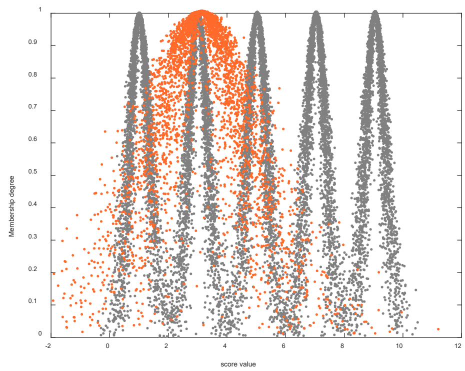

Figure 6

Figure 5: Cloud Diagram of Market Risk Assessment

Figure 6: Cloud Diagram of Policy Risk Assessment

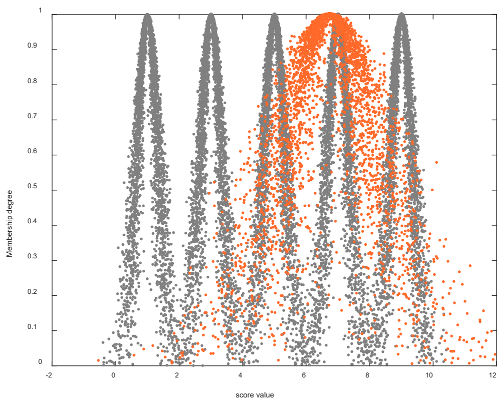

Figure 7: Cloud Diagram of Benefit Risk Assessment

From the analysis of Figure 3 to Figure 7, we can observe that within the primary indicators, finance risk and policy risk tend to be relatively low, market risk leans towards moderate, while operational risk and benefit risk tend to be relatively high. The primary risk assessment indicators, derived from cloud diagrams and risk indicator cloud parameters, are as follows: benefit risk > operational risk > market risk > finance risk > policy risk. Similarly, based on the cloud parameters of the 18 primary risk assessment indicators, the magnitude of risk can be determined. Based on this, project stakeholders can formulate corresponding strategies to mitigate or reduce the losses associated with risks.

According to the virtual cloud calculation, the WSMC risk indicator cloud parameters are determined to be (5.6249,1.4683,0.5548). Additionally, the results of the similarity cloud are depicted in Table 4.

Table 4: Membership Degree.

Evaluation Level Standard Cloud	Low Risk	Relatively Low Risk	Moderate Risk	Relatively High Risk	High Risk
Membership Degree	0.3055	0.6825	0.9786	0.9005	0.5317

Based on Figure 8 and Table 4, the WSMC project is positioned between moderate and relatively high risk levels, with a slight inclination towards moderate risk. According to the weighted risk assessment indicators of WSMC, benefit risk and operational risk emerge as the primary influencing factors. This finding aligns with practical observations, highlighting the need for rigorous examination and meticulous data review to ensure the most precise evaluation of project risk.

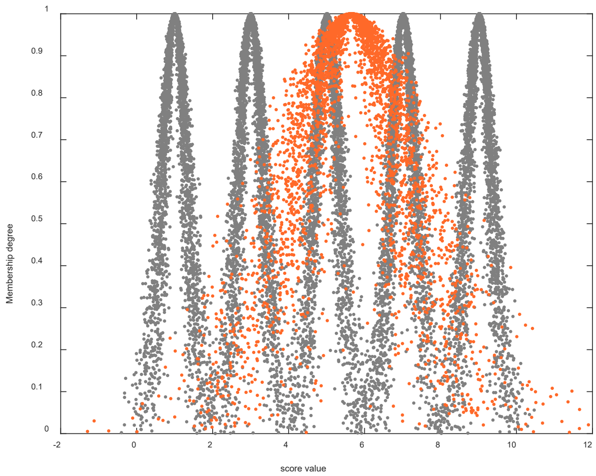

Figure 8: Cloud Diagram of WSMC

4. Conclusions

Risk assessment is crucial for participants in WSMC project to devise effective investment strategies. However, existing methods often fall short in adequately addressing the inherent complexity, ambiguity, and unpredictability of such projects, relying heavily on qualitative descriptions and overlooking key characteristics in the evaluation process. In response, this paper proposes an evaluation approach that combines combined weighting and normal cloud modeling to quantify the risks associated with WSMC, thereby offering valuable insights for project implementation.

Initially, the paper identifies finance risk, operational risk, market risk, policy risk, and benefit risk as the primary risk assessment indicators, along with 18 secondary risk assessment indicators. These indicators form the basis for a comprehensive evaluation system that integrates qualitative and quantitative elements. The weights assigned to these indicators are determined using a combination of the AHP and the entropy weight method. Subsequently, a standard cloud model is constructed based on predefined risk levels, followed by the establishment of a comprehensive evaluation cloud model through scoring of evaluation indicators using historical data, expert opinions, and project-specific considerations. Finally, the model's feasibility is validated through example verification, with results presented in the form of cloud diagrams.

Through analysis, it is found that the overall risk of WSMC project falls between moderate and relatively high risk levels, leaning towards moderate risk, which is consistent with reality. Comparing the cloud diagrams of each primary indicator reveals that benefit risk > operational risk > market risk > finance risk > policy risk. Managers can propose relevant strategies to reduce risks by comparing the secondary risk factor indicators of benefit risk and project finance risk using cloud diagrams.

While this paper offers a novel approach to safety assessment in WSMC project and introduces the research framework for mapping quantitative descriptions to qualitative concepts, it primarily relies on combined weighting for determining risk factor weights. Future research will explore alternative approaches to weight determination to provide managers with more effective guidance.

ISSN 2616-5902 Vol. 6, Issue 2: 235-242, DOI: 10.25236/AJBM.2024.060234

References

[1] Hojjati-Najafabadi, A., Mansoorianfar, M., Liang, T., Shahin, K. and Karimi-Maleh, H. (2022). A review on magnetic sensors for monitoring of hazardous pollutants in water resources. Science of The Total Environment, 824, 153844.
[2] Karimidastenaei, Z., Avellán, T., Sadegh, M., Kløve, B. and Haghighi, A. T. (2022). Unconventional water resources: Global opportunities and challenges. Science of the Total Environment, 827, 154429.
[3] Yang, D. and Yang, Y. (2021). Hydrological cycle and water resources in a changing world: A review. Geography and Sustainability, 2(2), 115-122.
[4] Wang, W., Ren, L., Deng, C., Wang, Q. and Yu, J. (2022). The water-saving management contract in China: current status, existing problems, and countermeasure suggestions. Water, 14(19), 3116.
[5] Xie, H., You, J. and Yang, X. (2019). Comprehensive Evaluation Model of Contract Water Saving Management in Irrigation District. Sustainability, 11(20), 5772.
[6] Hu, H., Wang, X., Gao, Z. and Guo, H. (2021). A real option-based valuation model for Shared Water Saving Management Contract. Journal of cleaner production, 289, 125442.
[7] Schewe, J., Heinke, J., Gerten, D., Haddeland, I., Arnell, N. W. and Clark, D. B. (2014). Multimodel assessment of water scarcity under climate change. Proceedings of the National Academy of Sciences, 111(9), 3245-3250.
[8] Ma, W., Li, X. and Wang, X. (2021). Water Saving Management Contract, identification and ranking of risks based on life cycle and best-worst method. Journal of Cleaner Production, 306, 127153.
[9] Li, Q., Shangguan, Z., Wang, M. Y., Yan, D., Zhai, R. and Wen, C. (2020). Risk assessment of China's water-saving contract projects. Water, 12(10), 2689.
[10] Wang, T., Tang, W. and Du, L. (2016). Relationships among risk management, partnering, and contractor capability in international EPC project delivery[J]. Journal of Management in Engineering, 32(6), 04016017.
[11] Yang, Y., Tang, W. and Shen, W. (2019). Enhancing risk management by partnering in international EPC projects: Perspective from evolutionary game in chinese construction companies[J]. Sustainability, 11(19), 5332.
[12] Jokar, E., Aminnejad, B. and Lork, A. (2021). Assessing and prioritizing risks in public-private partnership (PPP) projects using the integration of fuzzy multi-criteria decision-making methods. Operations Research Perspectives, 8, 100190.
[13] Noorzai, E. (2021). Public–private partnership risks in conflict zones and solutions: case study for Afghanistan. Journal of Infrastructure Systems, 27(1), 05021001.
[14] AL-Aga, S. F. R. and Burhan, A. M. (2023). Risk Assessment in BOT Contracts using AHP Technique. Journal of Engineering, 29(1), 61-75.
[15] Patel, T. D., Haupt, T. C. and Bhatt, T. (2020). Fuzzy probabilistic approach for risk assessment of BOT toll roads in Indian context. Journal of Engineering, Design and Technology, 18(1), 251-269.
[16] Smith, J. and Jones, A. (2018). Qualitative Risk Analysis in Project Management: A Critical Review. Project Management Journal, 49(4), 87-97.
[17] Brown, C. and Williams, B. (2019). Exploring the Effectiveness of Qualitative Risk Analysis Techniques in Construction Projects. Construction Management and Economics, 37(6), 1-15.
[18] Chen, L. and Wang, Y. (2021). Application of Qualitative Risk Analysis Methods in Environmental Engineering Projects: A Comparative Study. Journal of Environmental Management, 277, 111345.
[19] Kumar, S. and Gupta, R. (2022). Evaluation of Qualitative Risk Analysis Techniques for Healthcare Projects: A Case Study Approach. International Journal of Healthcare Management, 1-15.
[20] Liu, B., and Li, J. (2021). A New Fuzzy-Rough Set-Based Normal Cloud Model for Knowledge Representation and Reasoning. Information Sciences, 543, 87-104.
[21] Zhu, C. and Zhang, L. (2022). Normal Cloud Model Based Fault Diagnosis Method for Rolling Bearing in Wind Turbine Gearbox. Mechanical Systems and Signal Processing, 161, 108070.
[22] Wang, L. and Liu, J. (2023). Normal Cloud Model for Risk Assessment of Cyber-Physical Systems: A Case Study of Smart Grid. IEEE Transactions on Industrial Informatics, 19(1), 657-668.