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Risk assessment of infrastructure REITs projects based on cloud model: a case study of China

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Received 11 December 2022
Revised 25 February 2023
Accepted 28 March 2023

Abstract

Purpose – The need for infrastructure is growing as urbanization picks up speed, and the infrastructure REITs financing model has been crucial in reviving the vast infrastructure stock, alleviating the pressure on government funds and diversifying investment entities. This study aims to propose a framework to better assess the risks of infrastructure REITs, which can serve for the researchers and the policy makers to propose risk mitigation strategies and policy recommendations more purposively to facilitate successful implementation and long-term development of infrastructure REITs.

Design/methodology/approach – The infrastructure REITs risk evaluation index system is established through literature review and factor analysis, and the optimal comprehensive weight of the index is calculated using the combination weight. Then, a risk evaluation cloud model of infrastructure REITs is constructed, and experts quantify the qualitative language of infrastructure REITs risks. This paper verifies the feasibility and effectiveness of the model by taking a basic REITs project in China as an example. This paper takes infrastructure REITs project in China as an example, to verify the feasibility and effectiveness of the cloud evaluation method.

Findings – The research outcome shows that infrastructure REITs risks manifest in the risk of policy and legal, underlying asset, market, operational and credit. The main influencing factors in terms of their weights are tax policy risk, operation and management risk, liquidity risk, termination risk and default risk. The financing project is at a higher risk, and the probability of risk is 64.2%.

Originality/value – This research contributes to the existing body of knowledge by supplementing a set of scientific and practical risk evaluation methods to assess the potential risks of infrastructure REITs project, which contributes the infrastructure financing risk management system. Identify key risk factors for infrastructure REITs with underlying assets, which contributes to infrastructure REITs project management. This research can help relevant stakeholders to control risks throughout the infrastructure investment and financing life cycle, provide them with reference for investment and financing decision-making and promote more sustainable and healthy development of infrastructure REITs in developing countries.

Keywords Infrastructure financing, Infrastructure REITs, Risk assessment, Cloud model

Paper type Research paper

1. Introduction

Infrastructure is the projects that have a direct or indirect economic effect on output levels or productivity, including toll roads, transportation facilities, municipal services like water, electricity, heat and sewage and waste treatment, artificial intelligence infrastructure (Hueskes *et al.*, 2017). Investment in infrastructure is essential to the growth of the economy. The growth rate of infrastructure investment has, however, decreased as a result of China's new normal pursuit of steady economic growth, progressively shifting from a high-expansion incremental development model to a stock development model (Zhou *et al.*, 2022). Meanwhile, as cities become more populated and older infrastructure is used more frequently, there will be a continuing need for infrastructure that must be repaired and enhanced and for broader

This work was supported by the Natural Science Foundation of Guangdong Province, China under Grant [2023A1515011006].

Engineering, Construction and Architectural Management

0969-9988
DOI 10.1108/ECAM-12-2022-1142

development of new infrastructure. Additionally, building so much infrastructure puts a significant strain on the budget of the government. Therefore, in order to address the existing lack of liquidity and capital in huge infrastructure stock assets, as well as the excessive debt of investment organizations, the diversification of investors and the marketization of infrastructure are essential.

REITs (Real Estate Investment Trusts) is a significant instrument of real estate securitization that can promote the conversion of market-available low-liquidity real estate into high-liquidity financial assets (Campbell *et al.*, 2001). REITs, raising funds by issuing equity investment securities, invests in the property market and distributes comprehensive income to investors. Previous financing models are mostly debt-based, which has drawbacks such as limited financing channels, difficulties withdrawing capital and unequal investment returns. However, the equity-based of infrastructure REITs financing can compensate for the problems of previous financing models (Xiahou *et al.*, 2022). Infrastructure REITs, on the one hand, can help enterprises and governments reduce their leverage ratios and resolve debt risks, effectively revitalizing infrastructure stock assets (Huang and Zhong, 2013). On the other hand, it possesses the characteristics of a public listing, which can provide social capital with multiple exit options and promote the diversification of infrastructure investment entities in order to address the problem of insufficient investment (Coskun *et al.*, 2017). Therefore, infrastructure REITs is an important investment and financing tool for infrastructure. It has been instrumental in attracting diverse investors and building sustainable infrastructure.

Some countries have already issued policies and systems related to REITs, and have developed in practice by releasing REITs financing-related products (Zhang and Hansz, 2022). The types, numbers and asset sizes of REITs issued by the United States hold a prominent position on the international market. For example, American Tower Corporation (AMT) is a corporate REITs that holds, operates and develops wireless broadcasting communication assets. Australian REITs issue another regulated fund product LIF (Listed Infrastructure Fund) instead of infrastructure classification. Listed Infrastructure Fund invests in operating infrastructure assets including toll roads, airports and docks. According to wind statistics, by the end of 2020, the total number of publicly offered REITs in the world was 903, of which the total market value of US REITs accounted for 60%. As of June 2021, China's first batch of nine publicly offered infrastructure REITs has been successfully launched, raising a total of 31.403 billion yuan. The strategic placement was 22 billion yuan, accounting for 70.77% of the total issuance. REITs is relatively mature for developed countries, but infrastructure REITs is still in the experimental and demonstration stage in China. Mature REITs experience can provide valuable reference for infrastructure REITs in China and promote the practical application in developing countries. For infrastructure has the characteristics of long operation period and large investment scale compared with general engineering projects, it has certain risks of its own, such as industry risks, policy risks, operational risks, etc., as well as risks brought by the REITs model (Cotter and Roll, 2015). At present, there is currently a lack of risk assessment literature for infrastructure REITs projects, as well as a risk assessment index system for this problem, which provides an opportunity for this paper.

The purpose of this paper is to propose a framework to better assess the risks of infrastructure REITs. Firstly, identify and evaluate the risk factors of infrastructure REITs in China. Then, establish a cloud-based model assessment method to assess the overall risk level of infrastructure REITs projects. In order to achieve the objectives, this study established the risk index evaluation system of infrastructure REITs by collecting and analyzing data through questionnaires. Also, the study analyzed the project risk level qualitatively and quantitatively based on cloud model through the combined weight of AHP and Entropy, which brings a new cloud perspective to the risk evaluation of infrastructure REITs. This report helps infrastructure REITs finance participants manage risks across the financing life cycle and gives investors with a basis for investment and financing decisions. More importantly, it can effectively reduce the potential risks in the financing of infrastructure REITs, improve the overall risk management level of infrastructure REITs and promote the more sustainable development of infrastructure REITs and the application in developing countries.

The remainder of this paper is organized as follows. Section 2 reviews relevant literature, while Section 3 describes the research methodology in detail. In Section 4, the risk assessment model is set up. Section 5 takes China as an example to apply the risk assessment model. Section 6 proposes the corresponding countermeasures for risk factors. Ultimately, Section 7 depicts the conclusion of this study.

2. Literature review

The related theoretical research lays the foundation for risk assessment of infrastructure REITs. Thus, this chapter makes a literature review, including Risk in infrastructure REITs and cloud model evaluation method.

2.1 Risk in infrastructure REITs

Risk, generally as the likelihood of an event, has a negative impact and the "impact" of its occurrence (Guo *et al.*, 2014). If the possibility of an event occurring is low, but the consequences or impact of the event are extremely high, then the occurrence of the event is extremely risky (Xu *et al.*, 2010). On the other hand, uncertainty can also increase the risk of infrastructure REITs, and the risk is the result of internal and external uncertainties of infrastructure REIT (Choi *et al.*, 2010). Infrastructure REITs transforms real estate with continuous and stable income into financial products with strong liquidity through securitization, which are considered to be an important investment and financing model in infrastructure field. Infrastructure REITs can make up for the problems of previous financing models, such as narrow financing channels, difficulties in capital exit and uneven investment returns (Kim and Jang, 2012). Infrastructure REITs, on the one hand, can revitalize stock assets, reduce macro leverage ratios and resolve local debt risks (Gerlach *et al.*, 2015). On the other hand, infrastructure REITs have the characteristics of open listing, which can provide a variety of alternative exit for investors (Sha *et al.*, 2020). The risk of infrastructure REITs is different from the risk of traditional infrastructure financing. Firstly, from the perspective of project life cycle, risks of traditional infrastructure financing come from the entire life cycle, including the project bidding stage, construction stage and operation stage, from the project stage, while the risk of infrastructure REITs mainly comes from operation stage. Secondly, from the perspective of the financing model structure design, traditional infrastructure financing is a kind of debt financing, and its risk is mainly based on the credit enhancement of local governments and social capital. However, infrastructure REITs is a kind of equity financing, and its risks mainly come from the underlying asset risks borne by market-oriented entities.

The main income of REITs comes from its underlying assets operation and the asset appreciation (Fasanya and Adekoya, 2022). In addition, it also includes price difference income due to price changes in the secondary market (Kola and Kodongo, 2017). Thus, the underlying assets and the operation and management activities directly or indirectly determine the economic benefits of infrastructure REITs. Since infrastructure is the underlying asset, it inevitably faces long-term maintenance and depreciation risks (Frangopol and Liu, 2007; Yuan and Li, 2018). Specially, when project company obtains full ownership or management rights of the infrastructure, land use rights may face the risk of being unable to renew due to high land transfer fees (Capozza and Seguin, 2003), additional conditions and the extension of land use rights without approval (Dolde and Knopf, 2010). Additionally, the occurrence of force majeure events such as COVID-19 will also have an impact on REITs (Salami *et al.*, 2022). Therefore, the operation and management of infrastructure is an important basis for generating stable cash flow and maximizing the benefits of the project. In addition to the characteristics of the infrastructure, the external economic environment and trading market will also have an impact on infrastructure REITs (Payne, 2003). Fluctuations in interest rates and changes in inflation lead to changes in yields and prices in trading markets (Glascock *et al.*, 2002; Ngo, 2017). If market interest rates rise, infrastructure REITs will face fund price fluctuations, causing investors to lose money. Meanwhile, affected by the economic environment and operational management factors, the market value and cash flow of infrastructure projects may change, which will cause the risk of price fluctuations of infrastructure REITs funds (Deng and Ong, 2018; Li and Zhu, 2022). Secondly, supporting policies, laws and regulations related to infrastructure REITs play an important role in promoting REITs. However, infrastructure REITs in China lacks the operation experience and solid laws and regulations of infrastructure REITs because its development is still in the initial stage, which hinders the development of infrastructure REITs to a certain extent. Specifically, the REITs system is driven by taxation, which is reflected in the tax incentives and incentives in the establishment, duration and exit of REITs. Infrastructure REITs not only conducive to the issuer to quickly withdraw funds at a lower cost for reinvestment in infrastructure, but also conducive to attracting more diversified investments from social capital parties.

As of 2022, there are 14 infrastructure REITs projects in China, with a total issuance scale and a total market value of 54 and 62 billion yuan respectively. More infrastructure REITs projects will be launched in the future. Scholars are also actively exploring the key factors of the application of REITs in China to promote the development of urban construction (Xiahou *et al.*, 2022). Infrastructure REITs can solve problems, such as narrow financing channels, difficulties in capital exit and uneven investment returns. The risks of infrastructure REITs include both the uniqueness of infrastructure and the characteristics of REITs financing (Wu *et al.*, 2018; Zhang *et al.*, 2019). However, there is a lack of literature about risk assessment in REITs infrastructure projects. Moreover, infrastructure REITs in China still lacks mature operation experience and relevant laws and regulations, which is difficult to form a targeted infrastructure REITs risk evaluation index system. Thus, it is critical for the project implementation to deeply explore the potential risks of REITs and conduct risk assessment analysis, which is conducive to the sustainable development and implementation of infrastructure REITs in developing countries.

2.2 Cloud model evaluation method

Cloud model is based on traditional probability statistics and fuzzy set theory, which can handle the conversion between qualitative concepts and quantitative values, and effectively solve the problem of quantifying fuzzy concepts (Qin *et al.*, 2021)

The cloud model combines the fuzziness and randomness of index weights by calculating expectation, entropy and hyper-entropy to reduce the subjectivity of expert judgment and improve accuracy. Traditional evaluation methods have certain limitations. In the Monte Carlo Method (MC), it is necessary to convert the deterministic problem into a random problem, and the error is a probability error (Kalt *et al.*, 2022). The slow learning speed of the Back Propagation Neural Network (BPNN) leads to slow network convergence and falls into local minima easily (Zhang *et al.*, 2022). The Fuzzy Synthetic Evaluation (FSE) diverges the evaluation results due to different choices of fuzzy operators, and the determination of the index weight vector is highly subjective, so it is not suitable for evaluating many indexes (Zhao *et al.*, 2016). The cloud model can overcome the limitations of traditional evaluation methods, avoid the situation that the correct opinions of individual experts are ignored when dealing with many indicators, and fully display the qualitative results of the indicators through the cloud map. It enhances the visibility of risk results.

Cloud mode has been widely used in many research areas. In terms of risk assessment research Wu *et al.*, (2020) uses the cloud model to assess the investment risk of renewable energy in the countries along the “Belt and Road”, and uses the cloud model to obtain the overall risk according to its degree of membership, and provides decision-making suggestions for investors (Gao *et al.*, 2022). uses the combination of cloud model and multi-level Bayesian network to assess the risk of natural gas transmission stations, which provides a basis for reasoning risk and accident probability prediction (Wu *et al.*, 2022). constructed a fuzzy hierarchical cloud model to assess for renewable energy microgrids risks. In order to reduce the language uncertainty in the risk assessment (Yu *et al.*, 2021), conduct risk assessments on submarine pipeline leaks based on cloud model. The results verify that this method is a more accurate and effective risk assessment for submarine pipelines.

In summary, cloud models for risk assessment have been proven to be fruitful. In the risk assessment of infrastructure REITs, the cloud model method enhances the visibility of infrastructure REITs risk results, and the risk assessment results can be visually displayed through the cloud map. Also, it can deal with the uncertainty and ambiguity of the risk value, which is conducive to transforming the qualitative language of expert evaluation into a digital cloud image for quantitative analysis, reducing the randomness and ambiguity of risk evaluation indicators and improving the reliability and stability of the results.

2.3 Our position

The paper focuses on the risk analysis on infrastructure REITs. Specifically, we use the cloud model method to qualitatively and quantitatively evaluate the risks of infrastructure REITs. Our paper contributes to the literature in the following aspects. Firstly, despite its importance, the risk of infrastructure REITs have rarely been studied. Our paper fills this gap by investigating risks factors for the implementation of infrastructure REITs. Then, although many risk assessment methods developed by scholars, few are focused on infrastructure REITs. More importantly, randomization and ambiguity are rarely considered in risk assessment studies, but they are crucial for the risk assessment of infrastructure REITs. Thus, our paper uses the cloud model to tackle this problem, and proposes a risk assessment framework for infrastructure REITs to better address the complexity, ambiguity and randomness of infrastructure REITs projects. The proven effective and feasible cloud assessment method brings a new perspective to infrastructure REITs risk assessment literature.

3. Methodology

There will be various risks in infrastructure financing. Accurate identification and evaluation of risks are critical to the development of infrastructure financing. Infrastructure risk assessment consists of two parts. One is to identify and weight risk factors and the other is to evaluate the risk. However, it is hard to objectively represent the weight of the indications. Thus, researchers have applied a mix of subjective and objective index weighing methods, which can make up for the insufficiency of a single weight (Xu *et al.*, 2019). The approach for establishing the weights of indicators in this study is based on AHP and Entropy methods which is a combination of subjective and objective indicators.

Cloud model is based on probability statistics and fuzzy set theory, which can handle the conversion between qualitative concepts and quantitative values, and effectively solve the problem of quantifying fuzzy concepts (Qin *et al.*, 2021). The cloud model combines the fuzziness and randomness of index weights by calculating expectation, entropy and hyper-entropy to reduce the subjectivity of expert judgment and improve accuracy. Specifically, it can deal with the uncertainty and ambiguity of the risk value, which is conducive to transforming the qualitative language of expert evaluation into a digital cloud image for quantitative analysis, reducing the randomness and ambiguity of risk evaluation indicators.

To achieve the exploration and assessment of risk for infrastructure REITs, this paper has proposed a four-stage process in reaching the outcomes. The framework of this study is process-oriented in Figure 1 based on AHP and Entropy by cloud model evaluation.

3.1 Risk assessment framework

Figure 1 shows the infrastructure REITs risk assessment framework of the research, including research process, research method, research step and outcome. The research method of this paper is process-oriented, and the specific steps are as follows:

(1) Establish a risk evaluation index system. Based on the literature review and questionnaire analysis, as well as factor analysis and inspection, the infrastructure REITs risk evaluation index system is constructed and optimized to prepare for the calculation of the next index weight.

(2) Measure the weight of risk evaluation indicators. For each risk evaluation index has a different role and status in the system, its weight affects the accuracy of the evaluation results. Therefore, in order to better reflect the objectivity of financing

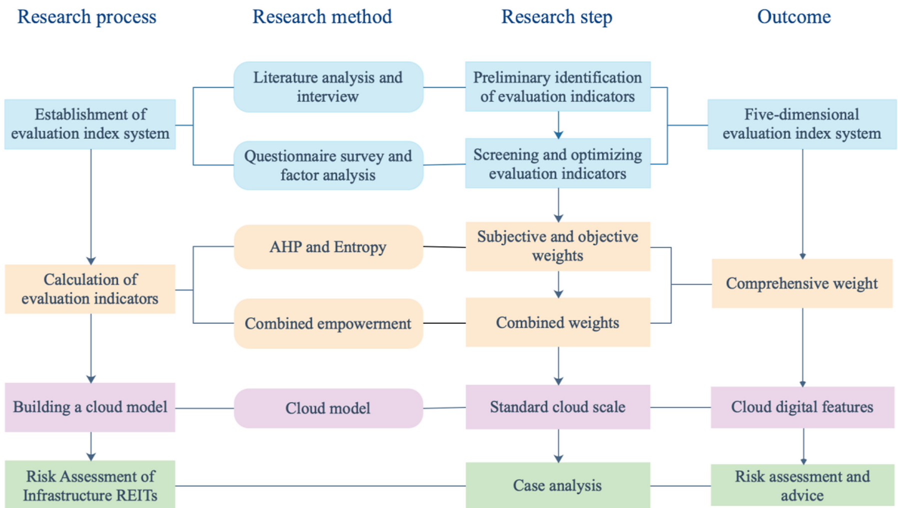

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Figure 1.
Risk assessment framework

risks and avoid the accuracy of evaluation results, this study combines AHP subjective weights and Entropy objective weights to obtain comprehensive weights, so as to pave the way for building a risk evaluation cloud model.

(3) Build a risk evaluation cloud model based on combination weights. After the comment set of the infrastructure REITs risk evaluation system is determined, experts will conduct bilateral scoring on each risk index, and the evaluation index cloud will be obtained through the reverse generator. Then, the previous step of the combination weight is brought into the cloud digital features to obtain a comprehensive cloud for infrastructure REITs financing risk evaluation.

(4) Select Practical significance cases of infrastructure REITs for analysis. Finally, the effectiveness and practicability of the model are verified, and risk assessment model are provided for infrastructure REITs financing.

3.2 Risk indicator system and data analysis

Risk identification, the basis of risk management, plays a key role in the results of risk assessment. This study builds an objective and comprehensive risk evaluation system through the literature review and questionnaire. This study contains two main aspects: (1) Identifies risk factors through literature review and preliminarily determines the risk indicators of infrastructure REITs. (2) Collect data on the important degree of risk indicators by questionnaires, and conduct factor analysis, validity and reliability tests of the data to obtain the final infrastructure REITs risk indicator system.

The purpose of this questionnaire is to explore the risk factors of infrastructure REITs from a macro perspective, mainly involving policy, law, economy and other aspects. In order to further revise and filter the selected indicators, this paper compiles a questionnaire based on the identified indicators (Table 1). A five-point Likert scale was used to make a questionnaire and scored according to the degree of importance (1, 2, 3, 4 and 5, respectively, indicate not important, not very important and generally important, more important, very important). The subjects of the survey are the government, university professors, securities practitioners, infrastructure project-related practitioners and personnel of consulting units. From March 2021 to October 2022, a total of 280 questionnaires were distributed. The questionnaires were distributed online by actively contacting the main responsible person of the participants, and at the same time, the scale of distribution was continuously expanded by snowballing. Through the recovery and analysis of the questionnaires, 19 invalid questionnaires that were filled out too quickly or answered too regularly were eliminated. A total of 261 valid questionnaires were obtained finally, and the effective recovery rate was 93.21%, which met the sample size requirements of the questionnaire survey (Everitt, 1975). The sample distribution is shown in Table 2 below.

To explore the main dimensions of the risk factors of infrastructure REITs, this study conducted a factor analysis on 24 indicators of the risk factors of infrastructure REITs. The results showed that the KMO index was $0.85 > 0.7$, and the Bartlett sphericity test was significant, $\text{sig} = 0.000 < 0.0001$, indicating that it was suitable for factor analysis. Through the dialectical method of "minimum eigenvalue is greater than 1", five-factor modes are proposed, and the eigenvalues of the first five factors account for $88.11\% > 50\%$ of the total variance, which meets the requirements.

In the first round of analysis, excluding factors with a small degree of commonality, because its small degree cannot extract effective information. In the second round of analysis, a "variance maximization" rotation was performed on the initial factor loading matrix through a Varimax orthogonal rotation so that each variable had a smaller loading on one and

Category	Indicators	Index explanation	References
Policy and legal risk C_1	Economic Policy Risk C_{11}	Risks arising from changes in relevant economic policies	Liu *et al.* (2017)
	REITs-related laws and regulations risk C_{12}	The imperfection of laws and regulations related to REITs and the risk of lack of stability	Erol *et al.* (2020)
	Land policy risk C_{13}	Risks faced by changes in policies related to land use, land development management etc	Puente-Sotomayor *et al.* (2021)
	Tax policy risk C_{14}	In the process of financing, due to the involvement of many relevant entities and a multi-layered operation structure, the transaction process will face multi-layered tax burdens, and risks arising from adjustments to national tax policies	Yang *et al.* (2018)
	Industrial policy risk C_{15}	Risks arising from changes to industrial development policies formulated by industries related to infrastructure projects, such as preferential subsidy policies	Jokar *et al.* (2021)
Underlying asset risk C_2	Infrastructure project land use rights renewal risk C_{21}	When the land use right expires, if the application for renewal of the land use right is not applied for or the renewal application is not approved, the risk of adverse impact on financing may be caused	Owolabi *et al.* (2020)
	Infrastructure project environmental risk C_{22}	Before financing, an environmental assessment of infrastructure projects is required. If the conditions required by environmental protection regulations are not met, infrastructure financing will face risks	Pesantez *et al.* (2022)
	Force majeure risk C_{23}	Risks arising from force majeure events such as wars, security incidents, global epidemics (COVID-19)	Chowdhury *et al.* (2020)
	Infrastructure project compliance risk C_{24}	Risks arising from the fact that infrastructure-related certificates and procedures have not been fully completed before financing, such as failure to sell in real terms, failure to achieve bankruptcy isolation etc.	Kola and Kodongo (2017)
	Infrastructure project cash flow forecast risk C_{25}	When predicting the cash flow generated by the project company's future operations, the risks arising from the influence of current policies, market environment and the project company's operating conditions and other factors	Chen *et al.* (2011)
	Infrastructure project operations management risk C_{26}	Management of infrastructure projects throughout their operation	Sundararajan and Tseng (2017)
	The project depreciation and maintenance risk C_{27}	If the highway maintenance standards applicable to infrastructure projects are increased, maintenance costs will be required to ensure normal operations	Jokar *et al.* (2021)

(*continued*)

Table 1.
Risk indicator system of infrastructure REITs

Category	Indicators	Index explanation	References
Trading market risk C_3	Liquidity Risk C_{31}	Due to the closed operation of infrastructure REIT, the subscription and redemption are not open, and they can only be traded in the secondary market, so there is a risk of insufficient liquidity	DiBartolomeo *et al.* (2021)
	Competitive risk C_{32}	There are potential competition risks arising from new or alternative projects within a certain distance of the subject matter	Piao *et al.* (2016)
	Supply and demand risk C_{33}	The risks caused by changes in supply and demand in the bond market due to the impact of the economic environment, market regulatory policies, government fiscal policies etc.	Alhassan *et al.* (2021)
	Interest rate risk C_{34}	Fluctuations in market interest rates will lead to changes in yields and prices in the bond market	Santandrea *et al.* (2017)
Operational risks of infrastructure REITs public funds risk C_4	Credit ratings and enhanced risk C_{41}	Risks of rationality and impartiality in the process of credit enhancement and rating of infrastructure REITs products	Efing (2020)
	Concentrated investment risk C_{42}	Public funds often adopt the way of diversified investment. If the investment in a single asset is concentrated, it will cause unsystematic risks to affect the fund investment	Zhou and Anderson (2012)
	Fund price volatility risk C_{43}	Affected by factors of economic environment and operation management, the market value and cash flow of infrastructure projects may change, which may cause the risk of price fluctuations of infrastructure funds	DeLisle *et al.* (2013)
	Information disclosure risk C_{44}	Risks of authenticity, completeness and readiness of relevant information disclosure	Deng *et al.* (2017)
	Delisting risk C_{45}	The risk may be triggered due to the termination of listing conditions stipulated by laws and regulations	Hodder *et al.* (2014)
Credit risk C_5	Moral hazard risk C_{51}	Moral hazard caused by participants' violation of their own professional ethics	Edelstein *et al.* (2010)
	Operational or technical risk C_{52}	Risks caused by defects in internal control or human factors in the process of implementing the underlying asset transaction	Wang *et al.* (2020)
	Default risk C_{53}	The risk of participating entities failing to repay debts on time or other defaults	Riddiough and Steiner (2020)

Source(s): Authors' own creation

Table 1.

only one factor. Each dimension has passed the Cronbach reliability analysis. Combined with the analysis results of literature review and questionnaires, the risk factor evaluation index system of infrastructure REITs is finally formed (Table 1). They are the five dimensions of policy and legal risk, underlying asset risk, market risk, infrastructure REITs public fund operation risk and credit risk.

Table 2.
The distribution of the questionnaire sample

Category	Description	Frequency	Proportion (%)
Respondent's institution	Government	68	26.1
	Enterprise	81	31.0
	Financial institutions	33	12.6
	Research institutes	19	7.3
	Consultants	34	13.0
	Law Firm	21	8.0
	Other third-party agencies	5	1.9
Education and experience	Bachelor degree or above	253	96.9
	More than 3 years of experience in infrastructure project management	225	86.2
	More than 3 years of investment and financing experience	202	77.4

Source(s): Authors' own creation

4. Risk assessment cloud model of infrastructure REITs using AHP and entropy approach

4.1 AHP and entropy approach

The subjective weighting method is susceptible to the influence of the subjective judgment difference of decision makers, which makes the weights biased. The basic principles of the objective weighting method are mostly mathematical statistical methods, which may not match the actual situation of the indicators. In order to avoid the limitations of the single weighting method, the weights obtained by the AHP and Entropy are integrated to obtain the optimal combined weights based on the game theory.

4.1.1 AHP-based weights. Firstly, normalize each column of the judgment matrix:

$$\overline{a}_{ij} = \frac{a_{ij}}{\sum_{t=1}^{n} b_{ti}}, i,j = 1,2,\cdots n \tag{1}$$

Secondly, add it line by line:

$$\overline{W}_i = \sum_{j=1}^{n} \overline{b}_{ij}, i = 1,2,\cdots n \tag{2}$$

Then normalize the vector, $\overline{W} = \left[\overline{W}_1, \overline{W}_2, \cdots \overline{W}_n\right]^T$, then the $W = [\,W_1, W_2, \cdots, W_n\,]^T$ is the required weight value.

$$W = \frac{\overline{W}_i}{\sum_{j=1}^{n} \overline{W}_j}, i = 1,2,\cdots,n \tag{3}$$

Finally, calculate the maximum eigenvalue of the judgment matrix λ_{max}:

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i} \tag{4}$$

(4) Consistency check. By calculating the consistency ratio of the judgment matrix *CR* 和 and the consistency index value *CI* is used to test the consistency of the judgment matrix. The value of the average random consistency indicator *RI*.

$$CR = \frac{CI}{RI}$$
$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{5}$$

When CI is closer to 0, it is considered that the consistency of the judgment matrix is better. When $CR < 0.1$ the judgment matrix is considered to pass the consistency test; If it is not, the judgment matrix needs to be reconstructed until it is qualified.

4.1.2 Weight based on entropy method. (1) Calculate the proportion of the j index to the i object. The evaluation system has n indicators, and each indicator consists of m samples.

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}(i = 1, 2, \cdots, m; j = 1, 2, \cdots, n)} \tag{6}$$

(2) Calculate the information entropy value of the j index. For a given j-th indicator, the smaller the difference between the original values of the sample x_{ij}, the larger the e_j is; If the x_{ij} s are all equal, the e_j takes the maximum value of 1.

$$e_j = -\frac{1}{\ln m} \sum_{i=1}^{m} (P_{ij} \ln P_{ij}) \tag{7}$$

(3) Calculate the coefficient of variance for the j indicator. The larger the difference coefficient, the more important the indicator, and the greater the weight.

$$g_j = 1 - e_j(j = 1, 2, \cdots, n) \tag{8}$$

(4) Calculate the weight of each indicator.

$$w_j = \frac{g_j}{\sum_{j=1}^{n} g_j(j = 1, 2, \cdots, n)} \tag{9}$$

4.1.3 Weight combination based on game theory. Firstly, construct the basic weight set $S = \{S_1, S_2, \cdots, S_n\}$,) find the most satisfying s^* in the possible vector set based on the idea of game theory. To find the most satisfactory weight vector is to optimize the weight coefficient α_k so that the dispersion between s and s_k is minimized, and the combined weight is obtained s^*, the steps are as follows:

$$S = \sum_{k=1}^{n} \alpha_k s_k^{\mathrm{T}} (\alpha_k > 0)$$
$$min \left\| \sum_{j=1}^{n} \alpha_j \times \boldsymbol{s}_j^{\mathrm{T}} - \boldsymbol{s}_i^{\mathrm{T}} \right\|_2 (i = 1, 2, \cdots, n)$$
$$\alpha_k^* = \frac{\alpha_k}{\sum_{k=1}^{n} \alpha_k} \tag{10}$$
$$\boldsymbol{s}^* = \sum_{k=1}^{n} \alpha_k^* \cdot \boldsymbol{s}_k^{\mathrm{T}}$$

4.2 Risk assessment of infrastructure REITs based on cloud model approach

The risk assessment of infrastructure REITs is a complex assessment system with ambiguity and randomness. The cloud model evaluation method can justly integrate the ambiguity and randomness of the problem. Risk assessment standards for infrastructure REITs adopts the fuzzy benchmark cloud method, which makes the assessment results more in line with the ambiguity and uncertainty of risk characteristics. Meanwhile, the evaluation results will not change drastically due to the fluctuation of the scoring data, and the accuracy of the evaluation results will not be affected by the increase of indicators. In addition, the unique cloud numerical parameters of the cloud model method can reflect the degree of risk membership, which enhances the reliability and stability of the results. The visual cloud map generated by the cloud converter realizes the visualization of risks.

(1) Digital characteristics of the cloud model

The concept of the overall characteristics of cloud model can be represented by three Digital characteristics: expectation Ex, entropy En and super entropy He, and a cloud map is formed after Matlab programming. Ex is the point value that can represent the qualitative concept in mathematics, reflecting the cloud center of the cloud drops. En is used to measure the ambiguity and probability of qualitative concepts comprehensively, reflecting the discreteness of cloud droplets. He is an uncertain measure of entropy, that is, the entropy of entropy, which reflects the condensation of cloud droplets. The size of the super entropy also indicates the discreteness and thickness of the cloud from the side. In the research, Ex states that "infrastructure REITs risk evaluation value", the greater the expectation value, the greater the risk evaluation value of infrastructure REITs; En means that "the reliability of the risk evaluation value of infrastructure REITs". The larger En, the lower the credibility of the risk evaluation results of the infrastructure REITs. The greater the super entropy value, the more random the infrastructure REITs risk evaluation results will be, and the more inaccurate the evaluation results will be.

(2) Determine Standard Cloud

Determine the comment set, and use the forward cloud generator to obtain the standard cloud based on the digital features of the cloud model corresponding to each comment, so as to form the evaluation standard cloud model of the index system. The formula is:

$$\left(\frac{x_{max}+x_{min}}{2}, 0.618\times 0.382\times\frac{x_{max}-x_{min}}{6}, He_0\right) \tag{11}$$

where x_{max} and x_{min} are the maximum and minimum values of the interval respectively.

(3) Determine the comprehensive evaluation cloud

Use the model to generate the evaluation cloud of each index, and integrate the comprehensive evaluation cloud of the project. The cloud model parameters are:

$$\begin{cases} Ex = \sum_{j=1}^{n} Ex_j w_j \\ En = \sqrt{\sum_{j=1}^{n} En_j^2 w_j} \\ He = \sum_{j=1}^{n} He_j w_j \end{cases} \tag{12}$$

5. Case study

This part will introduce the application of the proposed risk assessment framework for REITs with a case. On the one hand, it is used to verify the applicability and rationality of this research model. On the other hand, a detailed computational process is provided for the constructed model. It can provide reference for the risk management and prevention of infrastructure REITs.

5.1 Case information

The Industrial Park REITs is one of the first pilot projects of infrastructure REITs in China. It is currently the only public REITs project in a single industrial park in the Guangdong-Hong Kong-Macao Greater Bay Area. In June, according to the announcement of Bosera Fund, Bosera China Merchants Shekou Industrial Park REIT successfully completed the sale, with a total of 900 million shares, a total of 2.08 billion yuan of funds raised, and a public subscription application confirmation ratio of about 2.39%. Industrial-park REITs faces various risks in issuance, so this paper takes Bosera China Merchants Shekou Industrial Park REITs as an example to analyze the risks in the entire financing process. Bosera China Merchants Shekou Industrial Park REITs is the first public offering products in the Guangdong-Hong Kong-Macao Greater Bay Area. It has a positive demonstration effect that can promote the return of funds and promote the construction of new parks. This study used the project as a case study because some of the experts interviewed for this article had involvement with it.

5.2 Data collection and processing

To obtain the evaluation data, this paper designs two-way rating scoring questionnaire. Experts were asked to give a bilateral score of the highest score and the lowest wind for the risk level of 24 variables in the interval [0.100]. The higher the score, the greater the risk. Then, questionnaires were distributed to fifteen experts and project participants in the field of infrastructure REITs, including three experts in the field of infrastructure, three university professors, three government department managers, three securities practitioners and three tax professionals. The first round of consultation obtains the original scoring data, the second round provides other expert scoring data for reference, and the third round obtains expert revised data. After three rounds, the experts have no objection and obtain the final scoring data.

5.3 Determination evaluation criteria and cloud map

Adopting a cloud model based on the golden ratio (Tian *et al.*, 2020). The risk level score range is: $[X_{min}, X_{max}] = [0, 1]$. Very low risk (Yellow), Low risk (Red), Moderate risk (Green), Higher risk (Purple), Very high risk (Pink) (Table 3). According to equation (11) the cloud parameters

Risk level	Standard cloud parameters
Very low risk (Yellow)	(0.000, 0.103, 0.013)
Low risk (Red)	(0.309, 0.064, 0.008)
Moderate risk (Green)	(0.500, 0.039, 0.005)
Higher risk (Purple)	(0.691, 0.064, 0.008)
Very high risk (Pink)	(1.000, 0.103, 0.013)

Source(s): Authors' own creation

Table 3. Risk classification and standard cloud parameters

of the risk evaluation standard are obtained. By combining the interval ambiguity, the cloud map can accurately reflect the evaluation standard in Figure 2.

According to the standard cloud parameters, combined with the principle of forward cloud generator, a comprehensive standard cloud map is obtained through Matlab programming, as shown in Figure 2 below. The five evaluation benchmark cloud charts shown in Figure 2 represent “Very low risk”, “Low risk”, “Moderate risk”, “Higher Risk”, and “Very high Risk”.

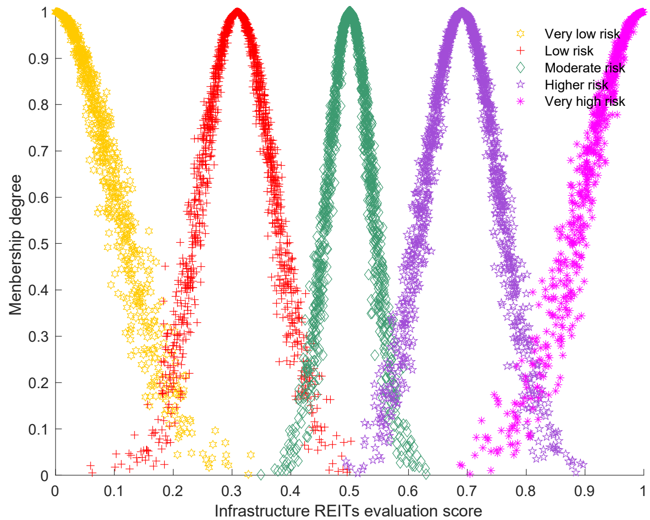
5.4 Determine the cloud parameters of the indicators and the comprehensive evaluation cloud of the project

According to the expert’s score for each index, using the reverse cloud generator (11)–(12), the cloud parameters of the final evaluation index are obtained. Then through Matlab programming, the forward cloud generator is used to convert the cloud parameters into a comprehensive risk assessment cloud map, as shown in Figure 3. Based on the index layer parameters, the collated comprehensive weights and the parameters of each index cloud model are substituted into the formula for calculation, and finally the comprehensive cloud model parameters for the evaluation of infrastructure REITs are obtained as: (0.642, 0.076, 0.011).

The comprehensive risk assessment cloud map in Figure 3 is blue. It can be seen that the comprehensive risk assessment cloud is between medium risk and higher risk, and is biased towards the higher risk benchmark cloud. The fluctuation range and cohesion of cloud droplets are small and strong.

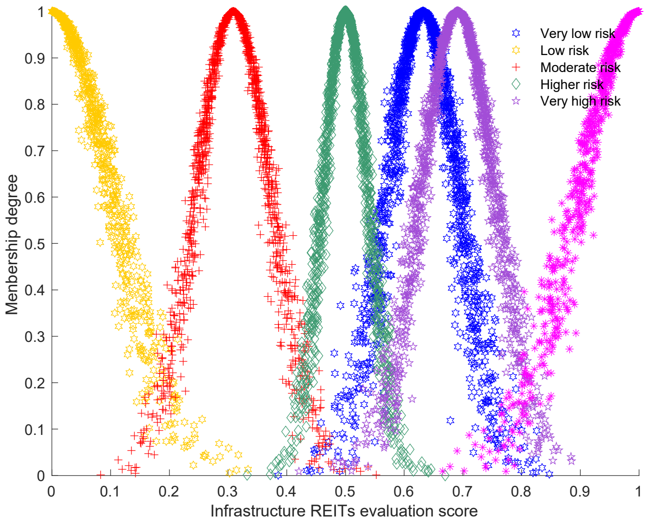
5.5 Results and analysis

From the blue cloud map shown in Figure 3 is the final result, it can be seen that the financing risk of this project belongs to the higher risk range. The abscissa of the cloud peak (Ex = 0.642) represents the risk assessment value, the bottom width (En = 0.076) represents the higher reliability of the risk assessment value; the thickness of the cloud line (He = 0.011)



Source(s): Authors’ own creation

Figure 2.
Standard cloud model

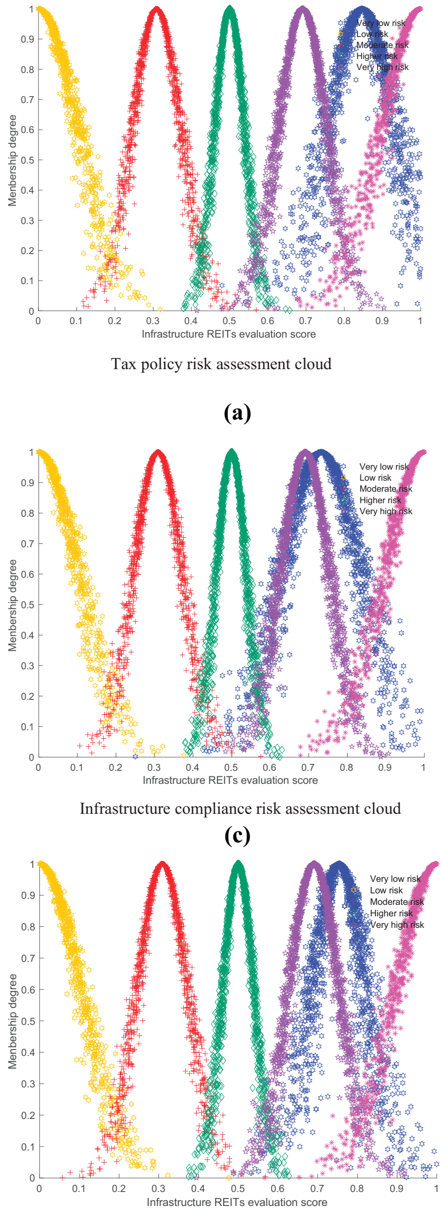


Source(s): Authors' own creation

Figure 3. The comprehensive risk evaluation cloud map

represents the higher stability of the risk assessment value. As shown in Figure 3, the peak of the blue cloud (Ex = 0.642) is close to the higher risk cloud. This result shows that the financing project is in a high-risk state (risk probability is 64.2%), which is very unfavorable for financing operation. Infrastructure REITs in China currently lack mature operation and management experience. The development-stage risks of infrastructure REITs are higher than the mature financing model. The market's acceptance of the development of this model remains low, which is consistent with the law of things' development. Thus, with continued market implementation and legal system improvement, as well as the government's active encouragement policies, investors' investment awareness and market acceptance of this model will gradually increase, and risk will stabilize and remain at a relatively low risk level. By improving the efficiency of financing operations and promoting the development of infrastructure construction, risk early warning and control capabilities can be strengthened.

There are 24 risk influencing factors and the evaluation value of risk influencing factors. The risk factors are divided into five levels: Very low risk (Ex = 0), Low risk ($0 < Ex \leq 0.309$), Moderate risk ($0.309 < Ex \leq 0.5$), Higher risk ($0.5 < Ex \leq 0.691$), Very high risk ($Ex > 0.691$). Also, six very high-risk influencing factors were identified: tax policy risk (C_{13}, Ex = 0.846), infrastructure operation management risk (C_{21}, Ex = 0.809), infrastructure project compliance risk (C_{27}, Ex = 0.732), liquidity risk (C_{32}, Ex = 0.783), termination risk (C_{42}, Ex = 0.754), default risk (C_{51}, Ex = 0.779), as shown in Figure 4. The above results show that different risk factors have different risk effects. Therefore, in practice, risk identification and monitoring should be strengthened to improve risk management capabilities and risk control efficiency. The evaluation results at the standard level are policy and legal risk (C_1, Ex = 0.803), underlying asset risk (C_2, Ex = 0.756), market risk (C_3, Ex = 0.597) and infrastructure REITs public fund operation risk (C_4, Ex = 0.682), credit risk (C_5, Ex = 0.634). The results show that it is necessary to study the risk of infrastructure REITs to the internal level of the system, which is conducive to improving the accuracy of risk prevention and control.



Tax policy risk assessment cloud

(a)

Infrastructure operation management risk assessment cloud

(b)

Infrastructure compliance risk assessment cloud

(c)

Liquidity risk evaluation cloud

(d)

Delisting risk assessment cloud

(e)

Default risk evaluation cloud

(f)

Source(s): Authors' own creation

Figure 4.
Index evaluation cloud model

6. Discussion

In order to overcome the shortcomings of the existing index weight determination and evaluation methods, this paper firstly adopts the subjective and objective comprehensive weight method combining AHP and entropy weight method. It can not only reflect the decision-maker's preference for attributes, but also avoid subjective arbitrariness to a certain extent, thereby making the decision-making result more objective and very close to the actual result. Second, this paper adopts the unique advantages of the cloud model method to evaluate the risk of infrastructure REITs, which takes into account the ambiguity and randomness of financing risk.

The research has proposed a framework to evaluate the risk of infrastructure REITs using the cloud model, making the following improvements. Firstly, the cloud model considers the uncertainty caused by the fuzziness and randomness in the evaluation process (Teng *et al.*, 2022). By incorporating numerous statistical theories, such as fuzzy mathematics theory and probability theory, it avoids the situation that the correct opinions of individual experts are ignored, therefore overcomes such limitations of previous evaluation methods. Then, the cloud model fully expresses the qualitative outcomes of the indicators, making the data more stable and reliable (Yu *et al.*, 2018). Although other frameworks using the Fuzzy Synthetic Evaluation Method (FSE) and the matter-element analysis evaluation method also combine qualitative and quantitative methods, they still have the defect that the forms to present the analysis results are not intuitive enough to show the degree of discreteness of the data (Zhao *et al.*, 2016). This framework using the cloud model solves this problem by visualizing the evaluation results through the cloud map (Gao *et al.*, 2022). Despite these advantages of the could model, some researchers also pointed out that it requires a certain learning cost and higher requirements for users (Wu *et al.*, 2020). As such, on the one hand, our proposed framework has been greatly improved and optimized by using the cloud mode comparing to previous evaluation models; while on the other hand, more efforts should be made on educating the practitioners in order to apply our proposed framework in practice.

It is found that policy and legal risk and underlying asset risk in the financing risk of infrastructure REITs in China are higher in the study. This is consistent with the conclusions of previous studies (Erol and Ozuturk, 2011). The Policy and legal risks exist throughout the life cycle of infrastructure REITs. Infrastructure REITs are sensitive to changes in infrastructure-related policies and laws due to the infrastructure is often regulated by the state in China. Whether the state supports and encourages infrastructure investment and financing policies directly or indirectly affects whether investors are willing to participate in infrastructure REITs investment. Specially, tax incentives are an important reason for the rapid development of REITs in Europe and the United States (Yang, 2021) As infrastructure is still in the early stage of development in China, real estate transactions and the establishment and operation of REITs are subject to higher tax burdens under the current tax system. Additionally, infrastructure REITs rely on the underlying assets of the infrastructure for their primary source of income, so the compliance and operation management of the underlying assets are critical. This is also consistent with the conclusions of this study (Zhang, 2021). Liquidity risk is the most significant market risk, followed by interest rate risk. The long investment recovery period is one of the main problems with infrastructure financing difficulties in China. Infrastructure REITs however can provide capital with multiple exit options and the ability to withdraw funds quickly. They will face greater liquidity risks if there are issues with the exit link. Infrastructure REITs are all equity-based in China, so the interest rates have little impact on equity REITs. In infrastructure REITs public fund operation risk, infrastructure REITs with public funds as a carrier is a unique issue in China. If the fund is delisted, it will cause a higher infrastructure REITs public fund operation risk and the entire financing behavior to fail to operate. As numerous entrustment or agency relationships, credit risk is unavoidable for most financial products. Stakeholders may make decisions based on maximizing their own interests. If the transparency and symmetry of information cannot be ensured during the operation at this time, it will inevitably damage the rights and interests of the participants (Song and Liow, 2022).

The relevant rules of infrastructure REITs are being gradually improved. In order to strengthen the prevention and control and supervision of financing risks, the paper provides the following suggestions. Firstly, it is recommended to improve the relevant policies and legal systems of infrastructure REITs, establish preferential tax policies in multiple links of fund operation, introduce tax credit system and special tax support policies to avoiding double taxation. Then, it should strengthen the cultivation and construction of professional market institutions and investment institutions. Finally, it is suggested that the regulatory authorities should focus on the establishment of the core system framework for REITs, simplify the regulatory approval procedures, for the financing involves various stakeholders which may have deviated their behaviors due to profit-seeking, thereby harming the interests of investors. In addition, it should establish a unified data platform to promote multi-party linkage and optimize supervision costs.

7. Conclusion

There are many risks and uncertainties in the financing process of infrastructure REITs. Therefore, this study uses a combined weights-cloud assessment model to identify, monitor and evaluate the potential risks of infrastructure REITs to improve the accuracy of risk management and the efficiency of risk management and control. Firstly, through literature review, questionnaires and expert interviews, this paper uses factor analysis results to divide and explain dimensions and finally identify the five-dimensional risk evaluation index system of infrastructure REITs (including 18 risk variables): policy and legal risk, underlying asset risk, underlying asset risk, trading market risk, operational risks of infrastructure REITs public funds, credit risk.

Secondly, this paper calculates the evaluation index weights by using the combination weighting method of AHP-Entropy, and conducts risk assessment for infrastructure REITs based cloud model. Through empirical analysis, this paper verifies the rationality and effectiveness of the model, and proposes risk prevention and control recommendations. The results of the study found that the overall risk of the financing project was relatively high, with a risk probability of 64.2%. Among these risks, the key risks are tax policy risk, infrastructure operation management risk, infrastructure project compliance risk, liquidity risk, termination Listing Risk, default risk.

Finally, the AHP-Entropy combined weights method of this study improves the accuracy of the weights of risk assessment indicators and avoids relying on the subjective opinions of experts. In addition, the cloud assessment model enhances the visibility of risks, and the assessment results can be directly displayed in different colors, which facilitates the monitoring and identification of risks. Based on the above advantages, the combined weights-cloud assessment model method can better meet the needs of infrastructure REITs risk assessment, and provide a method reference for subsequent infrastructure REITs risk research.

Infrastructure is an important support for social and economic development in China. In the face of infrastructure stock and insufficient investment, the implementation of infrastructure REITs plays an effective role. Thus, it is critical to identify the risks associated with infrastructure REITs throughout the life cycle, as well as to propose mitigation strategies and policy recommendations for key risks. The practical implications are described as follows: Firstly, identifying the risks associated with infrastructure REITs would assist decision-makers in controlling key risks rather than all risks. It is conducive to improving the risk management level and proposing targeted risk strategies according to key risks. Secondly, the risk assessment framework proposed in this study comprehensively considers the randomness and ambiguity of risks, and brings a new cloud perspective to the risk assessment of infrastructure REITs, which is beneficial for decision makers to better control and manage the infrastructure financing. Additionally, it can effectively reduce the potential risks in the financing of infrastructure REITs, improve the overall risk management level of infrastructure REITs and promote the more sustainable development of infrastructure REITs and the application in developing countries.

Although this study has made a significant contribution to infrastructure REITs implementation and project risk management, limitations still exist. It can be improved in the following aspects. The risk research of infrastructure REITs can be carried out based on the perspective of investment and financing of different entities. In addition, infrastructure as the underlying asset has diversity and complexity, and the indicator system can be slightly modified according to specific research to meet the needs of actual situations.

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