Analysis on Financing Risk of Waste Treatment PPP Project in Tianjin: An Empirical Analysis Based on Grey Correlation Degree

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Abstract: PPP is a new and effective financing mode for large-scale infrastructure construction, which has a broad development prospect. However, the progress of the project is not satisfactory. There are many reasons for the difficulty in landing PPP projects. However, according to the research, the key reason is the long construction cycle and low return on investment, which lead to the financing difficulty and high risk. Based on this, this paper investigated the pre-construction environment of the PPP project of the newly built domestic waste comprehensive treatment plant in Dongli district of Tianjin, by using Delphi method to establish a set of scientific and reasonable risk evaluation index system, and the entropy weight method is used to determine the weights of various risk factors, on the basis of the grey correlation method was used to construct the financing risk assessment model. According to this model, the risks faced by all major participants in the project are analysed and evaluated, and the results can provide references for the investment decisions of all participants, thus promoting the rapid and smooth development of PPP projects.

1. Introduction

PPP is also known as public-private partnership, refers to the cooperation between government and social capital to jointly participate in urban infrastructure construction. The project management mode to encourage private enterprise and private capital to cooperate with the government, making the public sector has the resources to participate in to provide public products and services, so as to realize the win-win or multi-win results, for example: Hebei Guan industrial park project using PPP mode of new urbanization, for 14 years, significantly improve the county financial income growth to nearly 50 times; Sewage treatment plant of Hefei has played an extremely important role in the comprehensive treatment of Chaohu lake pollution. It is precisely because of these remarkable breakthrough benefits that PPP project financing mode is increasingly favoured in the field of infrastructure construction in China. By the end of July 2018, a total of 7,867 projects and 11.8 trillion of investment had been entered into the project database of PPP comprehensive information platform nationwide. With 3,812 contracted projects and 6.1 trillion of investment, 1,762 projects started and 2.5 trillion of investment, the PPP model has been widely used in infrastructure construction in various provinces and cities in China.

As one of the four municipalities directly under the central government of China, Tianjin has witnessed rapid economic development, but so far there has not been a completed PPP project. In September 2018, Tianjin municipal government launched an open tender for the social capital of the PPP project of Dongli district municipal solid waste comprehensive treatment plant, which has been prepared for a long time, attracting great attention from all social parties. The construction of waste treatment plant can not only reduce the environmental pollution caused by traditional landfill methods, but also "turn harm into benefit, turn waste into treasure", such as digging the recycling value of packaging plastics and waste paper. However, PPP projects have the characteristics of long construction period, wide range of people involved, huge investment, etc., and the Chinese government and enterprises are still lack of relatively mature management experience for this new thing, resulting in many problems and even failures of some projects in practice. For example, Shandong Zhonghua power generation project, once known as the best PPP project in China, has no sense of long-term sustainable development of its decision-makers, and insufficient analysis of

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national policies and future market, which leads to a sharp drop in project operation income and the failure of cooperation between all parties. Tianjin Shuanggang waste incineration power plant, due to poor government regulation and public discontent, the project is in a dilemma; Lanzhou veolia water group, due to cost overruns, the company has been in the red. Faced with such a painful lesson, as the participants of the project, they are full of doubts and uncertainties about such projects, which therefore reduces the development speed of PPP projects in Tianjin. Due to the high degree of risk impact of PPP project, its core is still risk management [1]. In order to ensure the smooth progress of Dongli district waste treatment plant project, accurately identify the risk factors affecting the success of the project, establish a reasonable risk assessment model, and scientifically and effectively formulate risk prevention countermeasures have become a concern of all parties involved in the project and the society.

2. Literature review

In the past decade, although countries have implemented many public-private joint projects in some fields, there are still many problems in the effective risk management of these projects, and effective risk identification and reasonable risk sharing are still major problems that all participants will face. At present, domestic and foreign scholars have conducted a series of studies on PPP projects and risk assessment management. From the perspective of domestic literature, some scholars established the risk optimization model of PPP project by FAHP method. After determining the relevant risk factors through interviews, they put forward Suggestions for risk aversion from eight aspects [2]. Some scholars believe that qualitative risk analysis is superior to quantitative and semi-quantitative methods, and propose that the biggest reason for the risk of PPP projects in China is the lack of management culture [3]. From the perspective of foreign studies, some scholars adopted hybrid fuzzy method and cybernetic analysis network process (CANP) model to identify risks in Shared PPP projects, and verified the usability and rationality in an actual project in Iran [4]. Also, some foreign scholars have used ISM model to prioritize the 17 risks that may be faced by Indian road PPP project in its development stage, which is helpful for practitioners to better understand the interdependent relationship between risks [5]. However, after sifting through more than 600 literatures on PPP projects, it is found that about two-thirds of the empirical studies on PPP projects are related to rail transit, health industry and sewage treatment and so on [6]. For example, N. Carbonara et al. investigated and studied the risk management of 8 PPP expressway projects with Delphi survey method [7]. Samuel Carpintero et al. summarized the risk factors in the construction of 131 PPP sewage treatment plants in aragon, Spain, and provided Suggestions on the risk transfer in PPP contracts [8]. Through literature search found that both at home and abroad for waste plant project financing risk research less, and the reality of the PPP project financing risk, is a multi-faceted, multi-factor system, unpredictability, volatility is stronger, therefore, in this paper, based on the reference of existing research, from relevant expert proposal, using the entropy weight method to determine the weight of each risk factor, grey relational model is build new waste plant in Tianjin project financing risk analysis evaluation.

3. Identification of financing risk factors for PPP projects of garbage treatment

Many engineering projects have problems in cost, schedule and so on, and the inadequacy of risk management method is one of the main causes of project failure, such as: risk identification is not implemented at the beginning of the project, improper methods are used in the evaluation, or there is no follow-up mitigation strategy [9]. Due to the different economic, social and political environments embedded in PPP projects, the risks presented by PPP projects are different [10]. The project scale of waste treatment plant is large and the investment is high. Maintaining the operation only through garbage treatment fees or policy subsidies and other income sources will lengthen the investment recovery period of the project. In general, the treatment process of waste treatment is complex, and the technical level and production process level of the project are often required to be relatively high. And the franchise period that project company and government sign is general

longer. In this long period of time, national policies, internal financial structure of the company and other factors may change greatly, leading to the occurrence of risks. Therefore, effective and rapid identification and control of the project financing risk of waste treatment plant is an urgent problem to be solved before the project financing, as shown in Figure 1. Delphi method is a commonly used method in management decision-making, which is different from brainstorming. It mainly adopts the anonymous way to ask for expert opinions for many times, so that experts can give full play to their wisdom, knowledge and experience, and repeat the cycle again and again, and finally get a unified result that can represent the collective opinions of experts. This method is simple to operate, highly reliable, and has been used and verified in case analysis of several large PPP projects [1]. Based on this, this article selects the Delphi method, invite relevant experts from internal and external project and force majeure three aspects to consider, on the basis of reference to related research [11], dong li waste plant project in Tianjin all the main parties in the future may face the risk factors for identification, and building waste plant financing risk evaluation index system, as shown in Table 1.

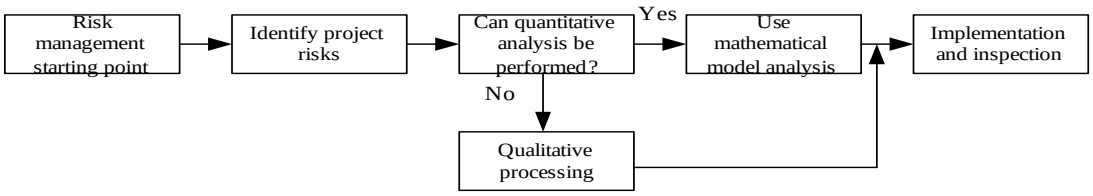

Figure 1 Project Risk Management Flowchart

Table 1 Risk Assessment Index system of Garbage Disposal Project Financing

Project internal	Project outside	Force majeure
Risks provided by the supporting equipment	Risk of government default	Risk of interest rate hike
Risk of cost overruns	Risk of contractor credit	Risk of inflation
Risk of insufficient return	Risk of cooperation barriers	Risk of demand change
Risk of delay	Risk of public opposition	Risk of policy changes

The index system can be divided into two levels. The first layer contains three elements, which are: project internal risk, denoted as a1; External risks of the project are denoted as a2 and force majeure risk a3. The three elements of the first layer respectively contain four sub-elements. For example, the internal risk of the project can be subdivided into the risk of supporting facilities (a11), the risk of cost overspending (a12), the risk of insufficient revenue (a13) and the risk of delay in the construction period (a14). Other risk factors are numbered and so on.

4. Construction of grey relational comprehensive evaluation model for PPP project of garbage treatment

Due to the risk factors of waste treatment plant project financing identified by Delphi method, the results may be affected by subjective factors of experts, resulting in unclear relationships between various risk factors and the formation reasons, which are grey. Therefore, this paper adopts the grey relational analysis method, which is different from the econometric tool commonly used in the field of economic management, to analyse the project financing risk of waste treatment plant. The basic idea of grey correlation is to judge whether the correlation degree is close according to the similarity degree of curve geometry. The closer the curve is, the greater the correlation degree

between corresponding sequences will be; otherwise, it will be smaller [12]. The specific steps are as follows.

4.1 Determine the set of evaluation indicators

Multi-index decision evaluation index set: each indicator also includes sub-indicators, and the attribute value is $A_{ij} = (a_{ij})$ $(i = 1,2,3...m; j = 1,2,3...n)$. Among them, m is the number of first-level indicators, n is the number of second-level indicators, and a_{ij} is the score value of risk indicators.

4.2 Establish decision matrix

The original data table or matrix can be obtained by collecting data according to the evaluation index system. However, due to the different nature of the indicators in the project, the dimensionality of the indicator data is not necessarily the same, which is not convenient for direct comparison and calculation. Therefore, in most cases, dimensionless processing should be carried out on the index value in the first place in the grey relational degree analysis. The general methods include mean value method, initial value method, interval value method, etc. [13]. In this paper, interval value method can be adopted to obtain the standardized decision matrix with the processed data value between [0,1]:

$$B_{ij} = \begin{bmatrix} b_{11} & ..... & b_{i1} \\ b_{12} & ..... & b_{i2} \\ ..... & ..... & ..... \\ b_{1j} & ..... & b_{ij} \end{bmatrix}$$

Indicators in the matrix can be divided into positive and negative ones according to the meanings they represent: Positive indicator (the bigger the index value, the better):

$$b_{ij}^{+} = \frac{a_{ij} - \min a_{ij}}{\max a_{ij} - \min a_{ij}} \tag{1}$$

Reverse indicator (the smaller the index value, the better):

$$b_{ij}^{-} = \frac{\max a_{ij} - a_{ij}}{\max a_{ij} - \min a_{ij}} \tag{2}$$

$\min a_{ij}$ is the minimum score of this index, and is the maximum score of this index.

4.3 Determine the sequence of ideal solutions

The so-called ideal scheme sequence C0, also known as the reference sequence, is the optimal set of evaluation indexes. The determination principle is: according to the economic meaning of each evaluation index, the optimal value of each index (that is, the expected value) is selected from all the evaluated objects to form the optimal sample sequence. If it is a positive indicator, the optimal value is the maximum set of the index value; In the case of a contrarian indicator, the optimal value is the minimum set of values in the index. As shown below:

$$C_0 = \{b_{01}, b_{02}, ...b_{0m}\} \tag{3}$$

Among them, $b_{0i} = \max_i a_{ij}$ or $b_{0i} = \min_i a_{ij}, i = 1,2,...m$

4.4 Calculate correlation degree

According to the above calculation, the correlation coefficient m_{ij} can be obtained, and the correlation coefficient matrix M of each index can be constructed. The calculation formula is as follows:

$$m_{ij} = \frac{\triangle \min \left| b_{ij} - b_{0i} \right| + \rho \triangle \max \left| b_{ij} - b_{0i} \right|}{\Delta \left| b_{ij} - b_{0i} \right| + \rho \triangle \max \left| b_{ij} - b_{0i} \right|} \tag{4}$$

ρ is the resolution coefficient, $0 \le \rho \le 1$, generally 0.5, $\triangle \min$ is the minimum difference of two levels, $\triangle \max$ is the maximum difference of two levels.

4.5 Entropy weight method to determine the weight of indicators

There are many methods to determine the weight which are mainly divided into two categories: subjective weighting and objective weighting. Subjective weighting method, such as expert scoring method, is simple and easy to be used in weighting, but it is easy to be limited by experts' own experience and knowledge. While simple objective weighting method has strong mathematical logic thinking, it may be inconsistent with the reality. Therefore, in order to improve the scientific rationality, we should not only consider the opinions of experts, but also try to make the evaluation results more consistent with the reality. It is a weight coefficient structure analysis method combining qualitative analysis and quantitative analysis with the basic idea of typical ranking by combining Delphi survey which is gathering experts' opinions with fuzzy analysis, then calculating the entropy value of the typical ranking according to the given formula, analysing the blindness, and dealing the data with potential variance [14]. According to the established standardized matrix and the definition of information entropy, the information entropy calculation formula [15] for a group of data is:

$$E_i = -\ln(n)^{-1} \sum_{j=1}^{n} f_{ij} \ln f_{ij} \tag{5}$$

Among them, $f_{ij} = c_{ij} / \sum_{i=1}^{m} c_{ij}$ $(i = 1, 2, ...m; j = 1, 2, ...n)$. If $f_{ij} = 0$, then define $\lim_{f_{ij} \to 0} f_{ij} \ln f_{ij} = 0$.

Thus, it can be concluded that the information entropy of each indicator is $E_1, E_2, ..., E_i$. The difference degree of the index is:

$$d_i = 1 - E_i \tag{6}$$

Finally, the calculation results of each index weight are:

$$W_i = \frac{d_i}{\sum_{i=1}^{m} d_i} \tag{7}$$

4.6 Grey correlation evaluation model based onentropy weight

According to the above analysis, a grey relational comprehensive evaluation model based on entropy weight method can be constructed. The basic idea of this model is to sort each index according to the degree of correlation, that is, to sort the evaluation objects by calculating the degree of correlation between each index and the ideal index. The model is shown as follows:

$$R = M \times W \tag{8}$$

R is the vector of comprehensive evaluation result. M is the correlation coefficient matrix of each index, and W is the weight distribution vector of each index. It can be seen from the above calculation that the value of is between 0 and 1. If the actual value is closer to the ideal value, the grey relational degree will be larger; otherwise, the grey correlation degree will be smaller.

5 Empirical analysis

After studying by the government, municipal solid waste comprehensive treatment plant in Dongli of Tianjin was decided to adopt PPP mode for construction and implementation. The project includes domestic waste incineration and power generation project, collaborative treatment project of food and kitchen waste and feces, and waste resource utilization project of construction waste, etc., with an estimated value of 2.659 billion and a cooperation period of 30 years. In view of the characteristics of this project, such as large construction scale, high investment amount and few referential experience, the method of combining expert scoring and mathematical modeling was adopted to rank and evaluate the uncertainty faced by all major participants of the project, so as to minimize the adverse impact of financing risks on all parties.

5.1 Determine the evaluation sample

Various indicators that can reflect the early-stage financing risk of the project have been identified above, but due to the different nature of a number of indicators, they cannot be measured by a unified standard. Therefore, with reference to relevant literature and in combination with the current actual situation of the project, the scoring criteria were set (as shown in Table 2). After the actual investigation, invited professor of Tianjin in the field of the PPP project management experts, doctoral students, government, construction enterprises and financial institutions staff, according to the study and its own experience, using expert scoring method of average, quantified, and the likelihood of the risk factors occur eventually get expert assessment, as shown in Table 3.

Table 2 Risk Rating Standards for Garbage Treatment Project Financing (part)

score / risk factor	[80,100）	[60,80）	[40,60）	[20,40）	[0,20）
Contractor credit rating	D	C	B	A	AA
Construction delay	Stagnation of the project	at least three delays in the early approval process	2-3 delays in the early approval process	1-2 delays in the early approval process	no delay
inflation	More than12%	6%-12%	3%-6%	0-3%	No inflation
Public opposition	Serious opposition	More opposition than support	flat	More for than against	All support
rate hike	More than 40%	30%-40%	20%-30%	0-20%	No fluctuations

Table 3 Table of Assessment of Risk Indicators for Financing Risk of Garbage Treatment Projects

participants	a_{11}	a_{12}	a_{13}	a_{14}	a_{21}	a_{22}	a_{23}	a_{24}	a_{31}	a_{32}	a_{33}	a_{34}
Government department	65	70	36	32	50	45	70	43	56	70	34	40
Social capital participants	40	50	75	55	50	26	74	45	58	78	36	68
Financial institutions	37	40	35	37	57	59	68	35	32	42	36	70
Other participants	35	30	35	40	53	58	64	47	38	40	37	48

Financing parties include China's commercial Banks, export credit agencies, multilateral financial institutions and non-bank financial institutions; Other participants mainly refer to contractors, subcontractors, professional operators (for certain special projects) and insurance companies undertaking the construction and operation of the project.

5.2 Establish the incidence matrix

According to Table 3, reference sequence $=(35,30,35,32,50,26,64,35,32,40,34,40)$ can be obtained, that is, the minimum value set of each risk indicator. According to equations (1) and (2), and the determined reference sequence, the risk evaluation index decision matrix of the project is determined:

$$A=\begin{bmatrix} 35 & 30 & 35 & 32 & 50 & 26 & 64 & 35 & 32 & 40 & 34 & 40 \\ 65 & 70 & 36 & 32 & 50 & 45 & 70 & 43 & 56 & 70 & 34 & 40 \\ 40 & 50 & 75 & 55 & 50 & 26 & 74 & 45 & 58 & 78 & 36 & 68 \\ 37 & 40 & 35 & 37 & 57 & 59 & 68 & 35 & 32 & 46 & 36 & 70 \\ 35 & 30 & 35 & 40 & 53 & 58 & 64 & 47 & 38 & 40 & 37 & 48 \end{bmatrix}$$

Secondly, dimensionless processing is performed on the matrix data (all indicators are reverse indicators).

$$B=\begin{bmatrix} 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 & 1.000 \\ 0.000 & 0.000 & 0.975 & 1.000 & 1.000 & 0.424 & 0.400 & 0.333 & 0.078 & 0.210 & 1.000 & 1.000 \\ 0.833 & 0.500 & 0.000 & 0.000 & 1.000 & 1.000 & 0.000 & 0.167 & 0.000 & 0.000 & 0.667 & 0.067 \\ 0.933 & 0.750 & 1.000 & 0.783 & 0.000 & 0.000 & 0.600 & 1.000 & 1.000 & 0.842 & 0.333 & 0.000 \\ 1.000 & 1.000 & 1.000 & 0.652 & 0.571 & 0.030 & 1.000 & 0.000 & 0.769 & 1.000 & 0.075 & 0.733 \end{bmatrix}$$

According to equation (3), because: $\Delta\left|b_{11}-b_{01}\right|=(1.000,0.167,0.833,0.000)$,so $\Delta\max\left|b_{11}-b_{01}\right|=1.000$ and $\Delta\min\left|b_{11}-b_{01}\right|=0.000$. According to the correlation coefficient formula, $\rho=0.5$, we can get: $m_{11}=\dfrac{\Delta\min\left|b_{11}-b_{01}\right|+\rho\Delta\max\left|b_{11}-b_{01}\right|}{\Delta\left|b_{11}-b_{01}\right|+\rho\Delta\max\left|b_{11}-b_{01}\right|}=0.333$, Similarly, the correlation coefficient matrix can be obtained:

$$M=\begin{bmatrix} 0.333 & 0.333 & 0.800 & 1.000 & 1.000 & 0.465 & 0.455 & 0.428 & 0.350 & 0.387 & 1.000 & 1.000 \\ 0.749 & 0.500 & 0.333 & 0.333 & 1.000 & 1.000 & 0.333 & 0.375 & 0.333 & 0.333 & 0.601 & 0.349 \\ 0.375 & 0.465 & 0.571 & 0.810 & 0.333 & 0.333 & 0.556 & 1.000 & 1.000 & 0.760 & 0.333 & 0.333 \\ 1.000 & 1.000 & 1.000 & 0.589 & 0.538 & 0.340 & 1.000 & 0.333 & 0.684 & 1.000 & 0.351 & 0.652 \end{bmatrix}$$

5.3 Determine index weight

In this study, a total of 20 questionnaires on the importance of indicators were issued to researchers in relevant fields, and 15 valid questionnaires were collected. According to the above mentioned entropy weight method to determine the steps of index weight calculation, the weight value of each factor of the project financing risk of waste treatment plant is obtained, as shown in Table 4. According to the data, in the financing process of this project, the obstacles to cooperation, policy changes, financial risks and other factors account for a large proportion. The reason is that the PPP projects in Tianjin are basically in the stage of preparation or identification, and the social capital parties have insufficient confidence in the government. Moreover, the cooperative operation period of the project is 30 years. If the management and operation are not good, the government may be transferred to new or reconstruction projects in the future, and the market returns are insufficient and other big risks. And that's what led to the PPP project, which was difficult to implement, slow development in Tianjin.

5.4 Comprehensive evaluation results

Table 4 Index Weight Value Based on Entropy Method

The evaluation index	$\sum_{j=1}^{n} f_{ij}\ln f_{ij}$	$-\ln(n)^{-1}\sum_{j=1}^{n} f_{ij}\ln f_{ij}$	$W_i=\dfrac{d_i}{\sum_{i=1}^{m} d_i}$
a_{11}	-1.774	0.990	0.036
a_{12}	-1.778	0.992	0.029
a_{13}	-1.773	0.989	0.040
a_{14}	-1.781	0.993	0.025
a_{21}	-1.770	0.987	0.047
a_{22}	-1.766	0.985	0.054
a_{23}	-1.728	0.964	0.130
a_{24}	-1.751	0.977	0.083
a_{31}	-1.767	0.986	0.051
a_{32}	-1.786	0.997	0.011
a_{33}	-1.753	0.978	0.079
a_{34}	-1.747	0.975	0.090

After calculating the comprehensive weight vector corresponding to each evaluation index and combining with the grey correlation coefficient matrix, the grey comprehensive evaluation value is

calculated. Finally, the financing risk evaluation results of the PPP project of garbage treatment plant in Dongli are obtained as follows:

R=（0.436，0.338，0.374，0.454）

According to the evaluation criteria of the grey correlation model, the greater the evaluation value is, the more similar the comparison series and the reference series are, that is, the smaller the risk is; otherwise, the greater the risk is. Therefore, the financing risks of the participants in the initial stage of the project are in descending order: social capital, financial institutions, government departments and other participants.

6 Conclusion

Waste treatment projects belong to the environmental protection cause of social public welfare. The traditional waste treatment method is government contracting, that is, the government should not only buy the equipment related to waste treatment, but also be fully responsible for the whole process of garbage recycling and treatment, so there is always the phenomenon of "spirit is willing, but strength is insufficient". With the continuous progress of social development in recent years, more and more projects in China's waste treatment plants adopt PPP financing. However, due to the late start of construction, the market gap is large. In order to promote the sustainable and steady development of the PPP project of waste treatment in Tianjin, promote the project to take effect, and ensure the sustainability of the project, the risk analysis of the project is of great significance. This paper adopts entropy weight assignment and grey relational model, on the basis of questionnaire, field investigation and reference to existing literature, to identify the risk factors of early financing and make scientific and reasonable evaluation.

There are two results. First, from the weight calculation results, it can be seen that the obstacles to cooperation between project participants and the risk of policy change account for a large proportion, which is mainly due to the lack of successful cases in Tianjin, and the PPP project is still in the stage of active exploration, so the social parties are still holding a wait-and-see attitude. Based on this, for the risk of obstacles to cooperation, in the early stage of cooperation, we should focus on how to improve the project supervision mechanism, establish a reasonable punishment system and other aspects, and share the risk among the participants reasonably. For the risk of policy change, as a government department, it can be considered to establish the corresponding accountability system, put an end to the phenomenon of arbitrary change of policy, be honest, abide by the laws and regulations, in order to enhance the confidence of other participants, so as to ensure the smooth implementation of the project. Second, according to the ranking results, the social capital side of the project is at greater risk. Therefore, relevant enterprises should formulate corresponding prevention and control measures as soon as possible according to the identified risk factors. For example, for the risk of force majeure, commercial insurance can be considered. In view of the risk of policy change, we may consider to formulate a government guarantee agreement. For the risk management in the operation stage, we can consider hiring senior management personnel in the operation period, or establishing a good relationship with the local experienced enterprises, and consulting related matters.

In conclusion, the risk index system established for the waste treatment plant project in Dongli district of Tianjin and the financing risk evaluation with the method of mathematical model have certain applicability and feasibility, which can provide reference for the investment decision of the project participants. Therefore, targeted supplements will be made in the subsequent research process, in the hope of providing more scientific and accurate decision-making basis for the project participants, so as to ensure the healthy, rapid and sustainable development of PPP projects.

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