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Research on Partner Selection of PPP Project in Wastewater Treatment Based on Grey Nearness Incidence

Hongjun Dai

School of Economics and Management, Huainan Normal University, P.R.China

Abstract: The PPP financing model of wastewater treatment project can help local governments to solve the problem of capital shortage and bring advanced management experience. It is the key factor of the PPP project for appropriate social partners selection. The evaluation index system of partner selection was established. It covered four fields: corporate reputation, financial ability, operational ability and management ability. Some experts apply the Delphi method to score the qualitative indicators. The most appropriate partner was decided according to the comprehensive evaluate results of Grey nearness incidence. The results of the example application show that the decision model and the index system can easily and effectively determine the ordering of partners, and help government departments to make better decisions.

Keywords: PPP project; Wastewater project; Partner selection; Delphi; Grey nearness incidence.

1. Introduction

Water is an essential strategic and economic resource for social and economic development. It plays an irreplaceable role in the process of human production development. The insufficiency and pollution of water resources have seriously affected the sustainable development of society and economy in China. In order to ensure the coordinated development of water resources and economy and society, the research on wastewater treatment and resource utilization has been carried out gradually. The practical experience of nearly 40 years shows that wastewater treatment and resource utilization is an effective way to reduce water pollution, improve the ecological environment and solve the urban water shortage. But there are two major problems in wastewater treatment industry in China, such as: heavy government financial pressure and low management level. The PPP mode is helpful to alleviate the financial pressure of the government and improve the management level. Government departments and social capital can cooperate closely in the PPP mode. It has been developed rapidly in China since 1984. The total transaction amount of PPP projects in China has reached 9.92281 trillion yuan by March 2018[1]. Many cases of the PPP projects show that it will bring many potential risks to PPP project to choose the inappropriate partner. Smith.N.J(1995) thinks that the franchisee must have basic experience is the primary success factor in the PPP projects[2]. It is the important factor for the success of PPP project to choose an appropriate partner. Therefore, domestic and foreign scholars have conducted research on this subject from different perspectives. Hatush et al.（1997） determined the evaluation index system for partner selection [3]. Zhang (2005) thinks that there are four dimensions in PPP project partner selection, such as financing ability, technical ability, management ability and control ability [4]. Fischer et al. (2005) provides a new idea for partner selection by using ant colony algorithm to simulate partner selection[5]. Song Bo et al. (2011) apply multi-objective group decision-making method to select PPP project partners [6]. Yi Xin (2016) puts forward a three-stage selection mechanism including access regulation, selection procedure and negotiation [7].On the basis of previous scholars' research, this study build up an evaluation criteria system to select partner for the PPP project of urban reclaimed water. The Delphi and Grey nearness incidence methods were used to select the appropriate partners from the candidates in this study.

2. Index System of Partner Selection of Wastewater Treatment PPP Project

PPP is not only a way of financing, so we cannot choose a partner only based on the economic strength to choose partners. The selection of PPP project partners should follow multi-dimensional evaluation criteria, focusing on their professional experience, talent structure, market position, credit level and other conditions. By referring to existing literature and investigating PPP projects such as environmental protection, water conservancy and municipal projects, this paper analyzes the common points and differences between PPP project partners and explores the key factors affecting the PPP project consortium partners.Based on previous scholars' research, we propose the index system of partner selection of PPP project in wastewater treatment from four perspectives of the company's reputation, financial capability, operation capability and management capability [8-10].

3. Grey Nearness Incidence Method

3.1. Brief introduction

Professor Deng Julong first invented the grey system theory in the 1980s.Professor Liu Sifeng carry forward and further develop the grey system theory in the later. The theory of grey system has many advantages, such as less original data, simple principle, convenient operation, and easy to mine data regularity. It makes up for the shortcomings of traditional mathematical statistics methods [11].

Table 1. Index Systems of Partners Selection of PPP Project in Wastewater Treatment

First-grade Index	Second-grade Index	Third-grade Index	Note
Choose partners	Company reputation	Qualification grade (X_1)	Quantitative index
		Credit rating (X_2)	Quantitative index
		Contract performance rate (X_3)	Quantitative index
	Financial capacity	Working capital (X_4)	Quantitative index
		Financing amount (X_5)	Quantitative index
		Financing cost (X_6)	Quantitative index
		Rationality of capital structure (X_7)	Qualitative index
	Operational capacity	Professional ability (X_8)	Qualitative index
		Number of technicians (X_9)	Quantitative index
		Management level (X_{10})	Qualitative index
		Hardware maintenance level (X_{11})	Qualitative index
	Organization and management capacity	Rationality of organizational structure (X_{12})	Qualitative index
		Risk control level (X_{13})	Qualitative index

Note: (1) qualification level: 8 points, 6 points, 4 points and 2 points for super level, 1, 2 and 3 levels respectively; (2) credit level: 10 points, 8 points, 6 points, 4 points and 2 points for AAA level, AA level, a level, B level and C level enterprises respectively.

The grey correlation analysis method is to measure the degree of correlation between factors according to the degree of similarity or dissimilarity of development trend among factors. It is to judge whether the connection is close or not according to the similarity degree of the geometry of the sequence curve. The grey correlation degree can be divided into nearness incidence and similar incidence. The grey nearness incidence is used to evaluate the proximity degree of two sequences in space. If the change trend of two data sequences is closer, it means that the correlation degree of two sequences is larger. Otherwise, the correlation degree between them is smaller.

3.2. Definition of the Grey nearness incidence

We assume the system behavior sequence X_i to be the same length as he system behavior sequence X_i,

$$X_i = (x_i(1), x_i(2), \cdots, x_i(n))$$
$$X_j = (x_j(1), x_j(2), \cdots, x_j(n))$$
$$S_i - S_j = \int_1^n \left(X_i - X_j \right) dt \quad (1)$$

$$\rho_{ij} = \frac{1}{1+\left|S_i - S_j\right|} = \frac{1}{1+\left|0.5\left(x_i(1)-x_j(1)\right)+\sum_{k=2}^{n-1}\left(x_i(k)-x_j(k)\right)+0.5\left(x_i(n)-x_j(n)\right)\right|} \quad (2)$$

ρ_{ij} is the gray nearness incidence between the system behavior sequence X_i and the system behavior sequence X_j [12].

3.3. Calculation of the Grey nearness incidence

(1) Determine the initial judgment index

We assume data sequence to form the following matrix:

$$\left(X_0, X_1 \cdots, X_m\right) = \begin{pmatrix} x_0(1) & x_1(1) & \cdots & x_m(1) \\ x_0(2) & x_1(2) & \cdots & x_m(2) \\ \vdots & \vdots & \vdots & \vdots \\ x_0(n) & x_1(n) & \cdots & x_m(n) \end{pmatrix}$$

$$X_i = \left(x_i(1), x_i(2), \cdots, x_i(n)\right)^T, \quad i = 1, 2, \cdots, m.$$

(2) handling the reverse indexes positively

According to the selected evaluation index, it is impossible for the index to be zero. Therefore, we handling the reverse indexes positively by the following formula:

$$X_i^* = \frac{1}{X_i} \quad (3)$$

X_{ij} is the original value of the reverse index.

We handling the moderate indexes positively by the following formula:

$$X_i^* = \sqrt{\left(X_i - X'\right)} \quad (4)$$

X_i is the original value of the moderate index. X' is the moderate value of the index.

(3) Normalization of the index

Because the dimensions of each index may be different, it is necessary to be normalize:

$$y_i = \frac{x_i^* - Min}{Max - Min} \quad (5)$$

Then got Y_i:

$$Y_i = \left(y_i(1), y_i(2), \cdots, y_i(n)\right)^T, \quad i = 1, 2, \cdots, m$$

(4) Identify the reference index sequence Y_0

The reference data sequence should be an ideal comparison standard. The reference data sequence can be composed of the best values of each index. And it also can be composed of other reference values according to the evaluation purpose.

$$Y_0 = \left(y_0(1), y_0(2), ..., y_0(m)\right)$$

(5) Calculate the grey nearness incidence between each evaluated index sequence and reference index sequence

ρ_0, ρ_1, ρ_2, ……., ρ_n

According to the grey nearness incidence, the higher the grey nearness incidence, the more appropriate the scheme is.

4. Case Analysis

4.1. Case introduction

The Municipal Construction Committee of H city initiated the wastewater treatment PPP project. The Municipal Construction Committee completed the following work: project initiation, value for money evaluation, financial affordability management demonstration, feasibility study report approval, construction scheme review, etc. Then, the Municipal Construction Committee issued an announcement to select the social capital partner of PPP project through competitive public bidding. At present, there are four alternative companies, such as A company , B company, C, company, D company.

4.2. Data processing and result analysis

We hired 5 experts to score the qualitative indicators in this study. Then, get the original data as shown in Table 2. We use the reciprocal method to process the inverse index in Table 2. We Normalize the data and get the normalization matrix. Then we got the reference index sequence. It was composed of the best values of each index. According to the calculation results in Table 3, the Grey nearness incidence of the four partners is 0.1353, 0.1653, 0.3237 and 0.1111, respectively. The grey nearness incidence of company C is the highest score among the four companies. Thus, the company C is the most suitable social partner.

Table 2. The Raw Data of the Evaluation Index System

Index	Unit	A	B	C	D
X_1	/	6	8	8	6
X_2	/	8	8	10	4
X_3	%	68	53	65	34
X_4	billion	0.94	0.89	1.08	0.83
X_5	billion	6.1	5.3	5.8	3.4
X_6	%	4.3	5.1	4.6	5.5
X_7	/	5	5	7	7
X_8	/	7	7	9	9
X_9	Person	44	55	53	33
X_{10}	/	5	7	7	7
X_{11}	/	5	7	5	5
X_{12}	/	7	9	9	7
X_{13}	/	9	7	7	9

Table 3. The Reference Sequence and the Evaluation Sequences

Index	Y_0	Y_A	Y_B	Y_C	Y_D
Y_1	1	0.0000	1	1	0
Y_2	1	0.6667	0.6667	1	0
Y_3	1	1	0.5588	0.9118	0
Y_4	1	0.44	0.24	1	0
Y_5	1	1	0.7037	0.8889	0
Y_6	1	1	0.2810	0.7011	0
Y_7	1	0	0	1	1
Y_8	1	0	0	1	1
Y_9	1	0.5	1	0.9091	0
Y_{10}	1	0	1	1	1
Y_{11}	1	0	1	0	0
Y_{12}	1	0	1	1	0
Y_{13}	1	1	0	0	1
ρ		0.1353	0.1653	0.3237	0.1111

5. Conclusion

We propose an evaluation index system of the PPP project in wastewater treatment. The index system includes four perspectives, such as corporate reputation, financial capability, operational capability and management capability. We apply Delphi method to score qualitative indexes of the candidate objects firstly. We use Grey nearness incidence model to select the most suitable partners. The Grey nearness incidence of the four partners is 0.1353, 0.1653, 0.3237 and 0.1111, respectively. So, the C company is the best partner. Through the above research, we hope to provide new ideas and references for the research of partner selection of PPP project.

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