Critical Factors Affecting the Concession Pricing for Rural Sewage Treatment PPP Project in China

Huaping XIONG[1] and Chunlai WU

School of Management, Wuhan University of Science and Technology, Wuhan 430081, China

Abstract. Concession pricing is the key to success of PPP project. There are many stakeholders in PPP project of rural sewage treatment and it is necessary to comprehensively consider social welfare, government financial pressure and reasonable interests of enterprise. The factors affecting concession pricing of PPP project are complicated and interrelated. This study analyzes the concession pricing target of different stakeholders in PPP projects of rural sewage treatment and identifies the critical factors. The relationship of these factors is clarified based on ISM. The results show that project expected rate of return is the direct influence factor and per capita disposable income is the root of the factor that affects concession pricing. The study results will provide governments with management implications to prepare equitable concession price.

Keywords. Concession price, influence factors, ISM, PPP project, rural sewage treatment

1. Introduction

Since 2014, Mainland China has been promoting the public–private partnership (PPP) procurement model in the infrastructure field widely. As of the end of December 2021, there were 10164 PPP projects in China Public Private Partnerships Center Database and a total of 4718 projects have been started with investment of 7.5 trillion yuan [1]. In order to reduce the finance pressure of government and improve the operational efficiency of social capital, more and more rural sewage treatment projects introduce private investors. As a new type of cooperation model, the PPP model links government and private investors to provide better services for infrastructure construction [2]. The PPP model has been introduced in different types of project such as waste-to-energy incineration sector, medical projects and smart city construction, etc. However, introducing private investors also makes the project more complex. The PPP project involves many stakeholders and it will be difficult to balance their rights and interests [3]. All stakeholders will take their own interests as the basic target and continue to compete or compromise and finally reach a consensus [4].

In PPP project, concession pricing is related to success of a project and needs to balance the right of government, sewage treatment enterprises and users. In the last

Corresponding author: Huaping Xiong, School of Management, Wuhan University of Science and Technology, Wuhan 430081, China; E-mail: 1415828772@qq.com.

decade, there have been various studies of the concession pricing for sewage treatment PPP projects. Most of them focused on influence factors for the concession pricing from the perspectives of enterprise cost, social welfare and risk sharing. For example, Wang Hongqiang believed that the key to PPP Projects was achieving reasonable risk and benefit sharing among the government, enterprises and public. Factors such as contract design and risk-benefit equivalence were considered [5]. Song Jinbo divided the factors that affect concession pricing into cash outflow and cash inflow, forming two systems [6]. Xiong Huaping used the cost pricing method based on the sewage load and the annual operating cost of enterprise to set concession price [7]. Han Mingjie analyzed the factors of concession pricing on the basis of proposing the variables of the risk sharing pattern and concluded that factors that determine the concession pricing were cost, investment rate of return and water inflow [8]. Zhang Yuchun, Zhang Pu comprehensively considered social and economic welfare when established the pricing model [9, 10]. Gao Hua constructed a pricing model based on the expected rate of return and cash flow of the project [11]. All these studies contribute significantly to the body of knowledge and also demonstrate the complexity and obscurity of critical factors of concession pricing.

Massive studies have looked at the urban sewage treatment project, but few studies have been done on the rural sewage treatment projects in the last decade. Critical factors affecting the concession pricing for rural sewage treatment PPP Project, such as the support level of rural resident is not sufficiently addressed in the literature. There are many differences between rural and urban sewage treatment projects. It is obviously unreasonable to apply the influencing factors of urban sewage treatment to determine the concession price of rural sewage treatment. The establishment of the concession price of rural sewage treatment involves many stakeholders. It is difficult and complex to formulate a reasonable concession price that satisfies the interests of various stakeholders. This study aims to identify the critical factors affecting concession pricing for rural sewage treatment PPP projects. The research methods adopted in this study are literature review and content analysis. Fig. 1 shows the flow of the overall research framework.
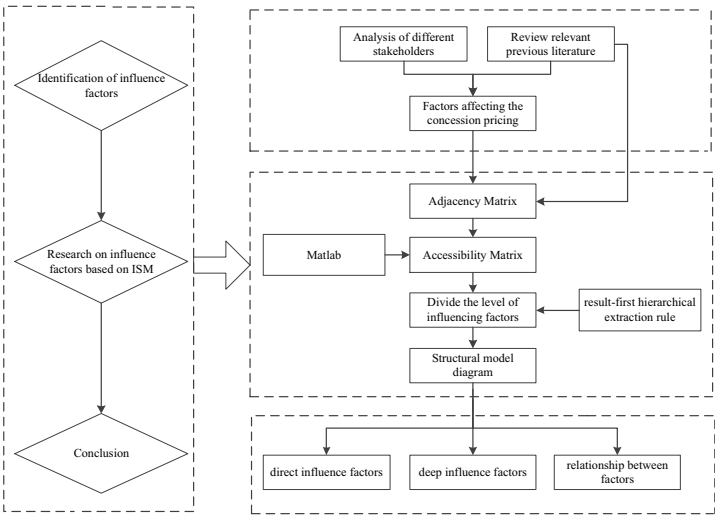

Figure 1. Flow of the overall research framework.

2. Analysis of Different Stakeholders

PPP refers to the cooperative relationship established by government and private investors based on a certain project in broad sense. It is a general term for a series of financing models of project [12]. Figure 1 shows different types of PPP models. Among them, the franchised PPP is the model commonly used in rural sewage treatment projects. Franchise PPP projects need to consider both the welfare of residents and the reasonable profits of sewage treatment enterprises. Private investors or enterprises need to charge for sewage treatment to recover investment capital and obtain profits. At the same time, rural sewage treatment PPP project should also provide services to the public to solve the problem of water pollution with a certain public welfare. However, the nature of such public welfare may limit the income of sewage treatment enterprises. In order to ensure the reasonable profits of sewage treatment enterprises and increase the enthusiasm of private investors, the government will provide appropriate subsidies to ensure the reasonable profits of enterprises. Therefore, the establishment of the concession pricing of rural sewage treatment PPP projects involves the rights and interests of the government, sewage treatment enterprises and residential users.

(1) Sewage treatment enterprises

Sewage treatment enterprises participates PPP Project of rural sewage treatment as private investors. Their primary target is still to make a profit. Their main income come from sewage treatment fee and government subsidies. Sewage treatment enterprises expect to increase the sewage load or extend the concession period or increase the concession price of sewage treatment to obtain more profits. But the sewage treatment price and government subsidies are controlled by government. On the other hand, sewage treatment enterprises expect to reduce investment and daily operating costs. Construction costs and operating costs are related to factors such as loan interest rates, inflation rates, the company's own operating capability, contract risks, uncontrollable risk and changes of related policies. The sewage load also affect the reasonable profits of enterprises and have an impact on concession pricing. The sewage load is affected by factors such as regional population and per capita water consumption, which will affect the formulation of concession pricing.

(2) Resident user

Compared with urban areas, the awareness of environmental protection and the level of regional economic development in rural areas are limited. Some rural residents do not accept the payment of sewage treatment fees for self-provided wells. Therefore, the degree of residents' support is also an important factor affecting the concession pricing. Rural residents which support sewage treatment projects not only expect to improve the surrounding water environment but also want to pay less fee. Factors such as sewage treatment effect, regional per capita income and resident price sensitivity also affect the concession pricing.

(3) Government

Government departments are both participant and system manager. As system manager, government needs to take into account the proper profits of enterprise and reasonable fees for rural residents. As participant, the government also needs to set the concession price within a reasonable range so as not to subsidize enterprise too much. There are many factors that affect concession pricing such as the effect of sewage treatment, the expected rate of return of the project, subsidies and preferential policies. On the one hand, the government expects the residents to pay sewage treatment fee within their tolerance range so the project can be carried out favorably and improves the

water environment. On the other hand, the sewage treatment industry should be controlled to ensure the rationality of the price.

The final price is affected by different stakeholders. The process of setting concession pricings of rural sewage treatment is affected by the government, enterprise and rural user. Various stakeholders have different pricing objectives for sewage treatment projects. The final pricing should consider the rights and interests of the three parties and set a reasonable price for sewage treatment.
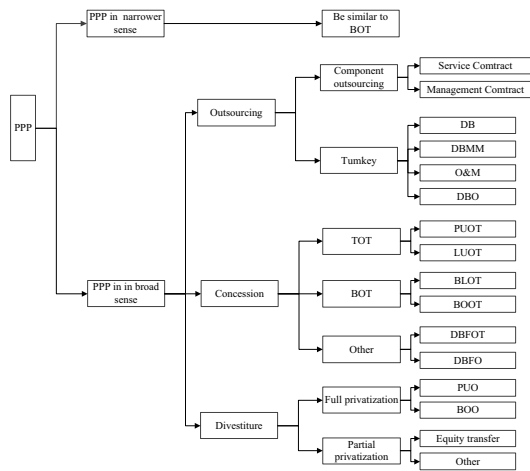

Figure 2. Classification of PPP operating mode.

3. Research on Influencing Factors Based on ISM

ISM(Interpretative Structural Modeling Method) was developed by Professor Warfield to analyze the structural of complex socio-economic systems. This method decomposes a complex system into several subsystem elements and uses tools such as directed graphs, matrices and computer technology to process information. ISM can clarify the relationship between elements and attach explanations to clarify the overall structure of the problem [13]. We can use ISM to transform complex systems into simple levels. The steps of establishing the ISM model are: (1) Identify the factors that affect the concession pricing and the relationship between them; (2) Derive the adjacency matrix and the reachability matrix to transform system structure into models; (3) Use Matlab to analyze the above matrices. Then the hierarchical structure model diagram of the charging pricing system is obtained and the main factors affect the concession pricing are determined. When formulating concession price, government should not only consider the public, but also should ensure the reasonable profits of the enterprises. By sorting out the literature and research results, 13 influencing factors are identified based on the analysis of the pricing objectives of various stakeholders. The 13 influencing factors are shown in table 1.

Table 1. Influence factors of rural sewage treatment fee.

Relevant stakeholders	Influence factors	Abbreviation of factor name
Sewage treatment enterprise	Loan interest rate	S_1
	Inflation rate	S_2
	Annual operating cost	S_3
	Construction investment cost	S_4
	Business capability	S_5
	Uncontrollable risk	S_6
	Sewage Load	S_7
	Project expected rate of return	S_8
Resident user	Per capita income level	S_9
	Support degree of residents	S_{10}
	Price sensitivity	S_{11}
Government	Effect of sewage treatment	S_{12}
	Support degree of government	S_{13}

The relationship between each influencing factor is determined through reading literature and analyzing each influence factor, which is shown in Table 2. "1" means that the factor in the column has an influence on the factor in the row. "0" means that there are no relationship between two factors.

Table 2. Adjacency matrix.

influence factor	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	S_{13}
S_1	1	0	0	1	0	0	0	1	0	0	0	0	0
S_2	0	1	1	1	0	0	0	1	0	0	0	0	0
S_3	0	0	1	0	0	0	0	1	0	0	0	0	0
S_4	0	0	0	1	0	0	0	1	0	0	0	0	0
S_5	0	0	1	0	1	0	0	1	0	0	0	1	1
S_6	0	0	1	0	0	1	0	1	0	0	0	1	1
S_7	0	0	0	0	0	0	1	1	0	0	0	0	0
S_8	0	0	0	0	0	0	0	1	0	0	0	0	0
S_9	0	0	0	0	0	0	1	1	1	1	1	0	0
S_{10}	0	0	0	0	0	0	1	1	0	1	0	0	0
S_{11}	0	0	0	0	0	0	1	1	0	1	1	0	0
S_{12}	0	0	0	0	0	0	0	1	0	0	0	1	1
S_{13}	0	0	0	0	0	0	0	1	0	0	0	0	1

Converting adjacency matrix into reachability matrix by Matlab, reachability matrix is shown in Table 3.

Table 3. Reachability matrix M.

influence factor	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	S_{13}
S_1	1	0	0	1	0	0	0	1	0	0	0	0	0
S_2	0	1	1	1	0	0	0	1	0	0	0	0	0
S_3	0	0	1	0	0	0	0	1	0	0	0	0	0
S_4	0	0	0	1	0	0	0	1	0	0	0	0	0
S_5	0	0	1	0	1	0	0	1	0	0	0	1	1
S_6	0	0	1	0	0	1	0	1	0	0	0	1	1
S_7	0	0	0	0	0	0	1	1	0	0	0	0	0
S_8	0	0	0	0	0	0	0	1	0	0	0	0	0
S_9	0	0	0	0	0	0	1	1	1	1	1	0	0
S_{10}	0	0	0	0	0	0	1	1	0	1	0	0	0
S_{11}	0	0	0	0	0	0	1	1	0	1	1	0	0
S_{12}	0	0	0	0	0	0	0	1	0	0	0	1	1
S_{13}	0	0	0	0	0	0	0	1	0	0	0	0	1

The set of column elements corresponding to the matrix element containing "1" in the row corresponding to the reachable matrix element Si is the reachable set $R(Si)$, and the set of column elements corresponding to the matrix element containing "1" in the column is the antecedent set $Q(Si)$. The common set is denoted as $P = R(S_i) \cap Q(S_i)$. According to the result-first hierarchical extraction rule method $(R(S_i) \cap Q(S_i) = R(S_i))$, the hierarchical decomposition method is used to decompose the elements hierarchically, and the five-level element division is obtained. The process of dividing the first level is shown in Table 4 and the final results of the hierarchy are shown in Table 5.

Table 4. Influence factor of first level.

influence factor	$R(S_i)$	$Q(S_i)$	$R(S_i) \cap Q(S_i)$	$R(S_i) \cap Q(S_i) = R(S_i)$
S_1	1, 4, 8	1	1	
S_2	2, 3, 4, 8	2	2	
S_3	3, 8	2,3,5,6	3	
S_4	4, 8	1,2,4	4	
S_5	3, 5, 8, 12, 13	5	5	
S_6	3, 6, 8, 12, 13	6	6	
S_7	7, 8	7,9,10,11	7	S_8
S_8	8	1-13	8	
S_9	7, 8, 9, 10, 11	9	9	
S_{10}	7, 8, 10	9,10,11	10	
S_{11}	7, 8, 10, 11	9,11	11	
S_{12}	8, 12, 13	5,6,12	12	
S_{13}	8, 13	5,6,12,13	13	

Table 5. results of the hierarchy.

Level of factors	Influence factor
The first level (L1)	S8
the second level (L2)	S_{13}, S_4, S_3, S_7
the third level (L3)	S_1, S_2, S_{10}, S_{12}
the fourth level(L4)	S_5, S_6, S_{11}
the fifth level(L5)	S_9

Combined with the relationship between the influencing factors of the adjacency matrix, the directional relationship between the levels is obtained, so as to determine the explanatory structure model diagram of the influencing factors, as shown in Figure 3.
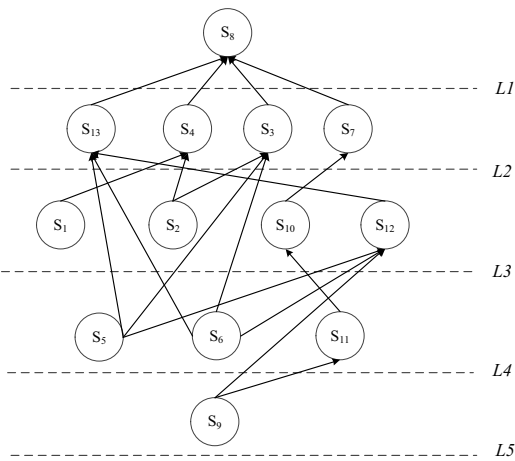

Figure 3.   Structural model diagram of the influence factors in rural sewage treatment project.

As shown in Figure 3, the expected rate of return (S_8) of L1 directly affects the concession pricing. The enterprise is the most critical member of the sewage treatment project. The goal of the enterprise is still to make profits and if enterprise don 't make enough profit from sewage treatment projects, it will be difficult to attract them again. The factors which belong to L2 to L4 levels are indirect influence factors, which affected by factors of the L5 level and directly affect the expected rate of return. The second level (L2) contains four influence factors which affect the expected rate of return and indirectly affect the concession pricing. The support degree of government includes government subsidies and preferential policies, which play a rule in project's cash inflow. There are only one influencing factor in L5, including per capita disposable income (S_9) which reflects the local economic development level. Rural users are both users and payers of sewage treatment projects. Their disposable income determines whether they have the ability and possibility to pay for sewage treatment projects, which is the deep-seated factor. The above interpretative structural model can clarify the level and relationship of the influencing factors to a certain extent, and provide some reference for the formulation of a reasonable concession price.

4. Conclusion

In China, more and more sewage treatment projects using the PPP financing model fail due to inappropriate concession price and other reasons. Therefore, it is necessary to identify the critical factors affecting concession pricing to ensure the success of the project. The results of this study offer many practical implications.

First of all, after analyzing the pricing needs of each stakeholder, a total of 13 factors are identified. The results show that the influencing factors at the government level are effect of sewage treatment and support degree of government. The pricing target of sewage treatment enterprises is mainly affected by the loan interest rate, inflation rate,

annual operating cost, etc. There are 3 influencing factors related to rural residents, including per capita income level, support degree of resident and price sensitivity.

Secondly, these important influencing factors can be divided into five levels. The expected rate of return of the project is the top-level factor, and the per capita disposable income is the bottom-level factor. The expected rate of return of the project has the most direct impact on the establishment of the concession price. Per capita disposable income is the deepest factor in the entire causal chain. When formulating the concession price, the impact of the expected rate of return and per capita disposable income should be taken into consideration carefully, in order to achieve a balanced state of rights among different stakeholders.

This study expands on previous research work by uncovering factors that influence concession pricing for rural wastewater treatment. In China, there has not been much research on the concession pricing display of rural sewage treatment projects, and rural sewage treatment projects cannot be simply compared with urban sewage treatment projects. The results of this study lay the foundation for the concession pricing of the rural sewage treatment PPP project.

Notably, projects with different characteristics and external will be affected by different factors, although only 13 influencing factors are discussed in this paper. Further research is needed to complement other influencing factors. In addition, to strengthen the general application of the obtained results, the findings should be further validated through more cases or empirical studies.

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