Multi agent risk sharing optimization of PPP project in urban garbage disposal -- Based on utility function considering of risk preference

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Abstract. PPP mode is widely used in urban garbage disposal projects. The key to success is to allocate PPP project risk reasonably and effectively. The paper firstly constructs a PPP project operation system of urban garbage disposal, and then the risk identification and the main sharing agents are analyzed. On the basis of the utility theory, the risk preference of each agent is considered, and the profit and cost efficiency function of the three agents, including investor, the government and the financial institutions is established. Finally, the function model is applied by a case of urban garbage disposal PPP project. The result shows that the proportion of risk sharing is related to the risk preference of each agent, and the optimal risk sharing proportion may make the overall utility of the project optimal.

1 Introduction

Garbage disposal is an important social livelihood project. It is necessary to introduce high quality social investors through PPP mode, reduce risk through long-term cooperation among each agent, and realize their interests' targets. Our government has clearly proposed that the PPP mode should be applied in the entire new garbage disposal project involving the government. However, in recent years, there are various of problems in the process of garbage disposal PPP project, such as miss election of site selection of the garbage disposal PPP project, the frequent occurrence of low price bidding, the emergence of enterprise speculation and the discharge of the pollutants. The risk identification is not specific, and the risk responsibilities of agents are not clear, which would affect the investment completion rate, the execution progress and performance of PPP project. Therefore, identifying risks in garbage disposal PPP project and sharing risk among the main agents is the key to successful operation of PPP project.

Scholars domestic and abroad put forward different views on how to allocate risks of PPP projects. In the aspect of risk identification, song Jin Bo [1] identified 10 key risks by conducting questionnaires to the government departments and SPV companies respectively, and put forward the strategy of sharing key risks between them. Ba shi [2] eliminated the factors that have less impact on the sharing of results based on the rough set theory. In the aspect of risk sharing, Li [3] suggested that enterprises should mainly share the microscopic level risk, while the macro risk can be shared by the government, or by the government and enterprises jointly. Wu Hai-yan [4] established an optimal risk sharing model of PPP project in water conservancy projects based on utility theory. In the aspect of the agent risk preference, Chung [5] evaluated the risk preference of major agent by a case analysis of the PPP toll road project in Australia.

Those studies generally believe that the risk of PPP projects should be shared by agents involved in the cooperation. However, quantitative analysis of risk sharing in the field of urban waste disposal and considering risk preferences of the main agents is not thorough enough. Thus, the paper constructs an operation system of garbage disposal PPP project, identifies the key risks in every stage of garbage disposal PPP projects, establishes a risk sharing model based on the utility theory with considering the risk preference of agent, and determines the proportion of risk sharing.

2 The risk system of urban garbage disposal PPP project

2.1 Urban garbage disposal PPP project operation system

The PPP project of urban garbage disposal is a long-term cooperation established by the government and social capital through the concession agreement. The project operation system is shown in Figure 1.

In the course of the system, the government carries out the project establishment and definition, puts forward the standard of the garbage disposal capacity of the project, carries out the planning and site selection of the project, entrusts the professional institutions to carry out the bidding work. The private investment institutions and the equity investment institutions finance jointly, and set

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up a franchise company, which is responsible for the construction and operation of the urban garbage disposal PPP project. The construction investment would be recovered by collecting garbage disposal fees from the government and selling electricity to the electricity companies. At the end of the concession, the franchise company should transfer the project to the government. Financial institutions provide loans, the government provides a commitment guarantee agreement to financial institutions, the environmental protection bureau supervises the operation of the project, and the power supply bureau buys online electricity of the project.

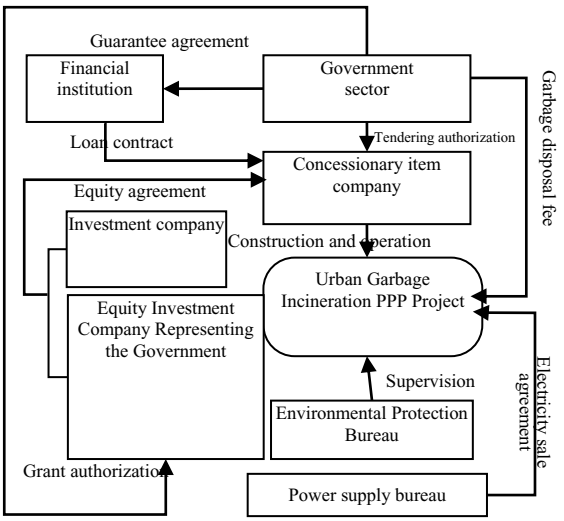

Fig.1. Urban garbage disposal PPP project operation system

2.2 Risk identification of urban garbage disposal PPP project

The operation system of the PPP project can be divided into six stages, including feasibility decision, bidding, financing, construction, operation and transfer. There are various risks in each stage that lead to the failure or the loss of the project. Therefore, clearer risk identification is the key prerequisite for risk sharing. 25 risk factors are summarized through the collation of the network, literature and garbage disposal, and through the interview and consultation with experienced person, who has the experience of garbage disposal project. The risk identification list of each phase of the urban garbage disposal PPP project is set up, as shown in Table 1.

2.3 Risk sharing agents of urban garbage disposal PPP project

Government, investors and financial institutions are the main risk sharing agents of urban garbage disposal PPP projects. Based on the theory of grounded and the statistics of questionnaires, the sharing of the key risk factors is arranged by the agents as shown in Table 1.

Table 1. Risk factors identification and sharing of urban garbage disposal PPP project

First level risk index	Second level risk index A_{ij}	Risk shareer		
		1	2	3
A_i				
Decision risk A_1	Site selection risk A_{11}	√		
	Design risk A_{12}	√	√	
Bidding risk A_2	Incomplete contract documents A_{21}	√	√	
	Insufficient capacity of franchisees A_{22}	√		
Financing risk A_3	Unreasonable financing structure A_{31}		√	√
	High Financing cost A_{32}		√	√
	Poor credit of financial institutions A_{33}		√	√
Construction risk A_4	Design alteration A_{41}		√	
	Construction delay A_{42}	√	√	
	Overrun cost A_{43}		√	√
	Mass defect A_{44}	√	√	
	Technology risk A_{45}		√	
	Inadequate supply of technical materials and equipments A_{46}		√	
Operational risk A_5	Project / operational change A_{51}	√	√	√
	Less Project income than expected A_{52}		√	√
	Raised Price in supply cost A_{53}	√	√	√
	Low management effici- ency of item company A_{54}		√	
	Low processing capacity and low standard A_{55}	√	√	
	Cost payment risk A_{56}	√	√	√
	Multi-agent collaboration risk A_{57}	√	√	√
	Government breach of contract A_{58}	√	√	√
Transfer risk A_6	Credit risks A_{61}	√	√	√
	Residual Value Risk A_{62}			
Joint adventure A_7	Irresistible risk A_{71}	√	√	√
	Public objection A_{72}	√	√	√

Note: the stakeholders 1,2 and 3 are government, project investors and financial institutions.

3 Risk sharing model of urban garbage disposal PPP project

The risk preference of agent should be considered. In addition, these agents usually make decisions on the premise of balancing their expected benefits and potential risks. Therefore, the utility of agents in garbage disposal PPP projects should be analyzed. The risk sharing model considering risk preference based on the utility theory is constructed as follows.

3.1 Variable settings

R_i is the risk preference measure of agent i, U_i is the risk-sharing utility of agent i, $U_{i,0}$ is the initial utility value of agent i without risk factors, V_i is the risk spillover benefit of agent i, C_i is the cost of agent i, C_{Ai} is the actual cost, C_{Ei} is the expected cost, λ_i is the risk ratio of agent i. λ_1, λ_2 *and* λ_3 is respectively the proportion of risk shared by government, Project investors, and financial institutions, and $\lambda_1+\lambda_2+\lambda_3=1$.

3.2 Risk sharing utility function

3.2.1 Risk sharing Utility function of each subject

The government initiates the garbage disposal project, which includes the cost of project investment and the cost of risk taking. Therefore, the cost of the government project is C=C_1 -$\lambda_1(C_{E1}$-$C_{A1})$. If the actual cost is greater than the expected cost, the cost of the government project is increased. The goal of the government is to minimize the cost, thus the government's utility is U_1=max {-C_1+$\lambda_1(C_{E1}$-$C_{A1})$}.

The goal of the investor is to maximize the income. The income of urban garbage disposal PPP project mainly includes garbage disposal fee, garbage incineration power generation and heating supplying. The risk spillover benefit of the investor is $V=\alpha \cdot C_2+\lambda_2(C_{E2}-C_{A2})$, where V is the total income of the project investor, α is the rate of return for investor projects, C_2 is the investment cost agreed upon by the investor when signs the contract. If the actual cost C_{A2} is greater than the expected cost C_{E2}, the total income is reduced. So the investor should consider the cost control, as well as the benefit from the project performance. Therefore, the utility function of investor is influenced by both the income V and the cost C, thus the utility function of the investor is $U_2(V_2, C_{A2})$.

The financial institution obtains income through the fund loan service, but also faces the financial risks such as the default of debt repayment. Therefore, the income V and the risk cost C should be comprehensively considered, and its utility function is $U_3(V_3, C_3)$.

3.2.2 Overall risk sharing utility function

The utility function $U_i(V_i, C_i)$ is a function of the benefit V_i and the cost C_i of agent i. The goal of urban garbage disposal PPP risk sharing system is to maximize the total utility of the three agents. Then the general utility objective optimization model of risk sharing is:

$$\text{Max}[U_1(V_1,C_{A1}) + U_2(V_2,C_{A2}) + U_3(V_3,C_{A3})] \quad (1)$$

$$Min\ C_A(C_{A1}, C_{A2}, C_{A3}) \quad (2)$$

The risk sharing by the three agents satisfies follows :

$$C_A = C_{A1} + C_{A2} + C_{A3} \quad (3)$$

$$C_{Ai} = \lambda_i \cdot C_A \quad (4)$$

$$C_{Ei} = \lambda_i \cdot C_E \quad (5)$$

The risk spillover benefits for PPP project investors, governments and financial institutions are as follows:

$$V_i = C_{Ei} - C_{Ai} = \lambda_i (C_E - C_A) \quad (6)$$

The formula (5) and (6) are replaced in the formula (1) and obtained

$$\text{Max}[U_1(\lambda_1(C_E-C_R),\ \lambda_1 \cdot C_A) + U_2(\lambda_2(C_E-C_R),\ \lambda_2 \cdot C_A) + U_3(\lambda_3(C_E-C_R),\ \lambda_3 \cdot C_A)] \quad (7)$$

3.2.3 Risk sharing utility function considering risk preference

Agents have different understanding and implementation of risk sharing. Their willingness and ability to share risks would have impact on the risk-sharing ratio. Therefore, a utility objective function with considering the risk preference of each agent is constructed. The sum objective function is as follows:

$$\Pi(U_1, U_2, U_3) = R_1 \cdot (U_1 - U_{1,0}) + R_2 \cdot (U_2 - U_{2,0}) + R_3 \cdot (U_3 - U_{3,0}) \quad (8)$$

R_1, R_2, and R_3 in formula (8) is respectively the risk preference coefficient of three agents, and the discount factor $\eta_i = \frac{R_i+1}{R_1+R_2+R_3+3}$ [6] is set. Agent with greater risk preference value has stronger bargaining power, thus its discount factor is greater. $U_1-U_{1,0}$, $U_2-U_{2,0}$, $U_3-U_{3,0}$ are the spillover effects of government, project investors and financial institutions as a result of risk taking.

Assuming that the minimum risk cost is the common expected cost EC of risk for investors, governments and financial institutions in urban garbage disposal PPP projects, thus, $C_A=\overline{EC}$. The risk sharing optimization model considering risk preference is as follows:

$$\text{Max}\ \Pi(U_1, U_2, U_3) = \text{Max}\{R_1 \cdot [U_1(\lambda_1 \cdot (C_E - C_R), \lambda_1 \cdot C_A) - U_{1,0}] + R_2 \cdot [U_2(\lambda_2 \cdot (C_E - C_R), \lambda_2 \cdot C_A) - U_{2,0}] + R_3 \cdot [U_3(\lambda_3 \cdot (C_E - C_R), \lambda_3 \cdot C_A) - U_{3,0}] \quad (9)$$

$$\text{s.t. Min } C_A = \overline{EC} \quad (10)$$

3.3 Risk sharing coefficient solution

For the formula (9), the partial derivative of λ_1、λ_2、λ_3 is derived by $\frac{\partial \Pi}{\partial \lambda_1}=0$, $\frac{\partial \Pi}{\partial \lambda_2}=0$, $\frac{\partial \Pi}{\partial \lambda_3}=0$. The optimal risk proportion of the government, the project investors and the financial institutions can be obtained by a function of the risk preference R_1、R_2、R_3. The optimal solution of the model can guarantee the risk sharing cost C_A minimization, and achieve the risk sharing optimization.

4 Case analyses

Changzhou has been selected as a pilot city for the disposal of food waste, and the recycling of food and kitchen waste. A PPP model franchise contract has been concluded between Changzhou City Administration Bureau and Jiangsu WELLE environmental Co. Ltd. The company signed the franchise framework agreement to be in charge of municipal kitchen waste collection, transportation and comprehensive disposal in five districts of Changzhou. The capital of the project is composed of state subsidy (31.8 million Yuan), government funded and commercial bank loans. The Changzhou municipal government invested 3 million yuan as the starting fund for the project, and WELLE loaned 50 million yuan from the commercial bank. WELLE has a franchise period of 25 years (including construction period of 1 year). The fee of kitchen garbage disposal is 239.5 yuan per ton.

The Changzhou government, WELLE and banks should share the irresistible risk. It is assumed that the expected cost of Changzhou municipal government, WELLE and banks is 3 million yuan, 10 million yuan and 5 million yuan respectively. Because the government is more likely to seek other partners, the opportunity cost is lower, the negotiation ability is stronger, thus the discount factor is larger. The investment recovery time pressure of the enterprise is greater, the discount factor is

relatively smaller. So suppose the risk preference coefficient of the three agents is 0.5, 0.2 and 0.3 respectively. The government's risk utility function is $U_1 = U_1(V_1, C_1) = -\frac{1}{570}C_1^2 + V_1 + 1$. The enterprise's risk utility function is $U_2 = U_2(V_2, C_2) = -\frac{1}{230}C_2^2 + V_2 + 1$. The bank's risk utility function is $U_3 = U_3(V_3, C_3) = -\frac{1}{350}C_3^2 + V_3 + 1$. The actual cost is C_A, and the initial utility value of the three agents is $U_{1,0}=1$, $U_{2,0}=1$, $U_{3,0}=1$.

$C_A=\overline{EC}=600$ can be obtained by formula (10). Bring $R_1=0.5$, $R_2=0.3$, $R_3=0.2$ into formula (9), and get:

$$\begin{aligned}\text{Max}\Pi\{&0.5\cdot[U_1(\lambda_1\cdot(300-600),\lambda_1\cdot 600)-U_{1,0}]+\\&0.3\cdot[U_2(\lambda_2\cdot(1000-600),\lambda_2\cdot 600)-U_{2,0}]+\\&0.2\cdot[U_3(\lambda_3\cdot(500-600),\lambda_3\cdot 600)-U_{3,0}]\}\end{aligned}$$

Set $\lambda_3=1-\lambda_1-\lambda_2$, $\frac{\partial F}{\partial \lambda_1}=0$, $\frac{\partial F}{\partial \lambda_2}=0$, the proportion of government risk sharing can be solved, $\lambda_1=0.1445$, and the proportion of enterprise risk sharing is $\lambda_2=0.5131$, the proportion of bank risk sharing is λ_3=1-0.1445-0.5131=0.3423. The entire utility of the three agents reaches a maximum value, the MaxΠ values 116.0844.

5 Conclusions

Conclusion 1: It is need to optimize risk identification and improve explicit contracts. With the reference of table 1, professional consulting units should be employed to identify the key risks in the whole process of urban garbage disposal PPP project. In the contract concluding, the rights and responsibilities of each agent should be clearly defined to restrict the behavior of each agent. A explicit contract should be formulated in the project and the content of the contract should be perfected.

Conclusion 2: The risk sharing of government by non-financial means should be strengthened. The result of the case shows that the financial risk sharing of the government is relatively small, and it is necessary to strengthen the non-financial risk sharing means, such as policy guidance, environmental regulation, supervision, providing guarantee and prolonging the franchise period.

Conclusion 3: The garbage disposal capacity and operation level of enterprises should be enhanced to reduce operational risks. Through the case analysis, enterprises share the greatest proportion of risk. Therefore, they need to improve comprehensive capabilities and reduce risk management costs firstly. Secondly, they need to improve the capacity of garbage disposal, to achieve cleanliness standards. Thirdly is to ensure investment in production facilities, equipment maintenance and renovation, and to ensure that the facilities are in good condition.

In conclusion, the urban garbage disposal PPP project involves many agents, and there are irresistible risks, which greatly increases the difficulty of the project implementation. Fully identifying the risk factors in the whole process, considering the risk sharing preference of each agent in the urban garbage disposal PPP project, could make scientific decision on risk sharing proportion of the government, enterprises and financial institutions. So that to realize the optimal allocation of risk under the premise of maximizing the total utility, and to provide reference for the decision-makers to reduce the risk management cost, which is helpful to promote the effective implementation of the project.

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