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Risk Analysis of Public–Private Partnership Waste-to-Energy Incineration Projects from the Perspective of Rural Revitalization

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Abstract: In China, more and more waste-to-energy (WTE) incineration plants are being delivered through public–private partnership (PPP) schemes in rural areas, which are focused on rural revitalization. These can not only deal with the ever-increasing solid waste but also provide renewable energy and thus benefit local societies. However, they usually endure a lot of risks due to long concession periods and complex contractual relationships. This research investigates the risk management of PPP WTE incineration projects from the perspective of rural revitalization. First, a preliminary list of 36 risks was derived based on a literature review. Second, a focused group discussion with eight experts was held to obtain the final list of 36 risk factors, taking into account rural revitalization. Third, a structured questionnaire survey was conducted to consult the risk frequency and risk severity. A total of 100 valid questionaries were collected. Finally, risk analysis and discussion were provided on the basis of the survey. The top 10 risks are rural appearance, payment risk, local employment, local economic development, local government succession, operation cost overrun, waste supply, construction cost overrun, revenue risk and price change risk. It indicates that (1) PPP WTE incineration projects can effectively promote rural development; (2) government authorities play a significant role in the sustainable development of PPP WTE incineration projects; and (3) the risk preference of rural PPP WTE incineration projects is social, economic and environmental risks.

Keywords: rural revitalization; waste-to-energy incineration plants; public-private partnership; risk analysis

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1. Introduction

Waste-to-energy (WTE) incineration projects are one kind of biomass power generation, which is considered resource-friendly and environment-friendly [1] and thus promoted by government authorities in the face of global climate change [2]. It is an important component of renewable energy, which could facilitate the optimization of the energy structure [3,4], the reduction of carbon dioxide emissions [5–7] and the promotion of economic growth [8]. WTE plants are widely adopted in a lot of countries and regions, including Accra of Ghana [9], Malaysia [10–12], Europe Union [13], Italy [14], Taiwan [15], Indonesia [16], Vietnam [17], Mainland China [18] and New Zealand [19]. In China, WTE incineration has developed rapidly since the first WTE incineration plant in 1988. WTE incineration projects deal with solid waste with the advantages of high volume reduction and less land resources consumption and energy recovery [20–22]. Figure 1 shows that municipal solid waste increased from 14.86 million tons in 2003 to 23.51 million tons in 2020 [23,24]. Meanwhile, the number of WTE incineration projects grows from 47 in 2003 to 463 in 2020. As high consumption usually leads to increased waste generation [13], there will be more solid waste generation in developing countries, including China. Accordingly, more WTE incineration projects are required in the future.

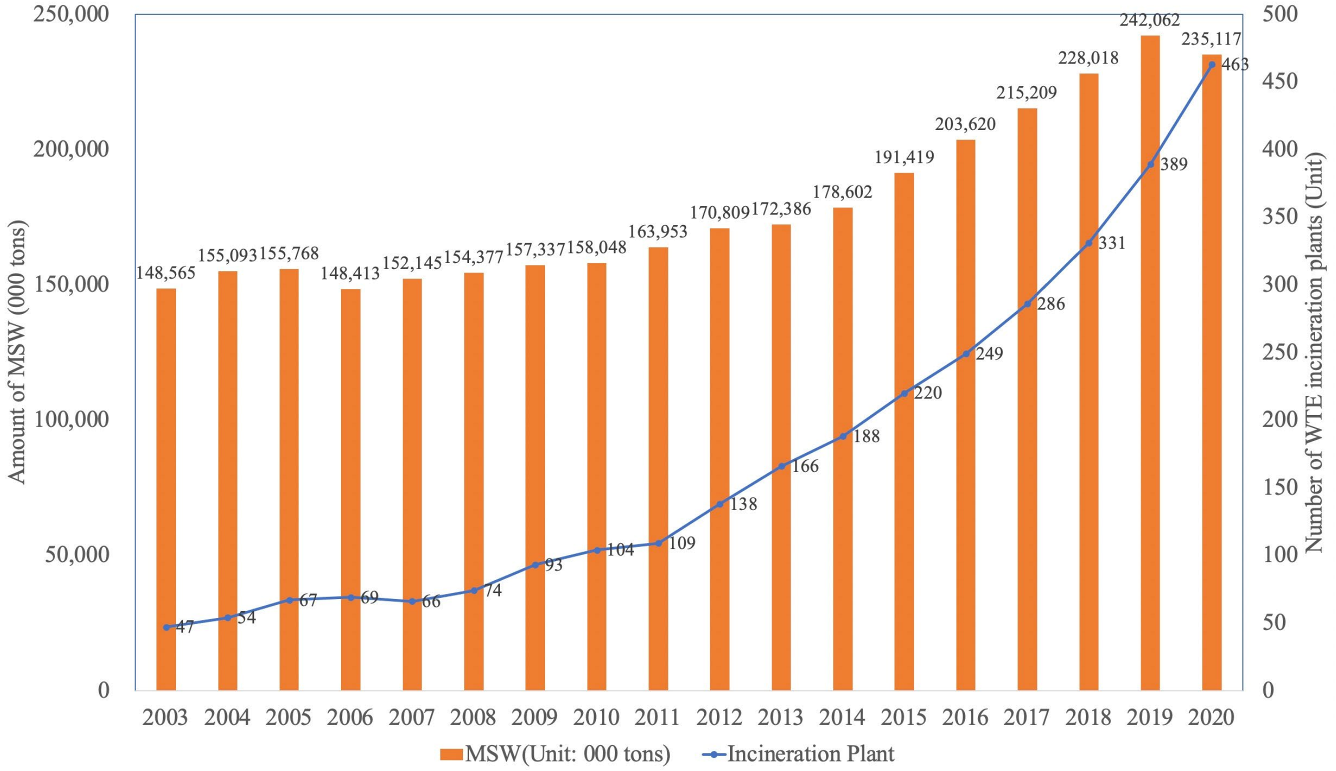

Figure 1. Municipal solid waste and number of WTE incineration projects in China from 2003 to 2020 [23,24].

The rapid growth of WTE incineration projects is highly related to the supporting policies of government authorities. Among these policies, feed-in tariff (FIT) subsidies play a significant role in developing WTE incineration plants [25–28]. Under the FIT system, the grid price from incineration plants is clearly set and is usually higher than that of thermal power plants. In 2006, the price was set as 0.25 CNY/kwh higher than local standard thermal power [29]. It was adjusted to be 0.65 in 2012 [30], which accelerated the growth rate of incineration plants, as shown in Figure 1. MOF issued "several suggestions on sustainable development of non-water renewable energy" on 20 January 2020 [31]. It is suggested to reconsider the price of WTE incineration power based on the development of the industry and cost variations and promote the tradable green certificate (TGC) scheme.

There exist a number of constraints for its development, including a huge amount of capital investment [9,32,33], management skills during the operation periods, etc. Public–private partnerships (PPP) provide a possible way by providing capital investments and management skills [34]. Most WTE incineration projects were delivered through a PPP scheme in China. It was reported that more than 70% of WTE incineration projects were operated in a PPP scheme [35]. Moreover, 108 PPP WTE incineration projects were deployed from 2012 to 2016, with a total investment of CNY (Chinese Yuan) 489 billion [35,36]. Meanwhile, there are a total of 111 WTE incineration projects deployed, as shown in Figure 1. The PPP projects account for 97% of the total of WTE incineration projects. There are two platforms for PPP projects: one is issued by MOF [37] and the other is announced by the National Development and Reform Commission (NDRC) [38]. Currently, there are 10,248 PPP projects on the former platform, and the total investment amount is 1621 billion CNY (Chinese Yuan). Among them, there are 202 incineration projects, with a total investment amount of about 115 billion CNY from 2016 to 2021.

Nevertheless, WTE incineration projects are also criticized for their occupation of scarce urban land resources and environmental pollution potential [33,34]. In this regard, more and more WTE incineration plants were delivered through a PPP scheme in rural areas, where rural revitalization is ongoing. The rural revitalization strategy was proposed in the 19th National Congress of the Communist Party of China (NCCPC) to accelerate rural development. In order to achieve it, the Central Committee of the Communist Party (CCCP) and the State Council (SC) issued the "Strategic plan for rural revitalization (2018–2022)" (refers to "Strategic plan" later) [39]. It is observed that more than 50% of incineration projects have been located in rural areas since 2016 [37].

PPP WTE incineration projects endure a lot of risks due to their complex contractual arrangements, a large amount of capital investment and long concession periods. On the one hand, WTE incineration projects endure inherent risks [40–42], including economic risks, technical risks, etc. On the other hand, PPP WTE incineration projects have their specific risks [35,43–46], including waste supply risk, public opposition risk, environment pollution risk, etc. These risks are a substantial challenge for both government authorities and private sectors. Inappropriately handling risks may lead to project failures. For example, the Liulitun incineration project and Wujiang incineration project failed due to operational risks and environmental risks, respectively.

Thanks to the joint efforts of a number of scholars worldwide, there exist a number of studies focusing on risk management of PPP WTE incineration projects, especially on risk identification and risk assessment. However, there are still potential improvements in the area. First, regarding the risk analysis in the previous studies, one potential assumption is that PPP WTE projects are located in urban areas. In China, more and more PPP WTE incineration projects are being built in rural areas [47]. It necessitates risk analysis of PPP WTE incineration projects from a different perspective. Second, risk identification was mainly developed through case studies [43,45,46,48]. A case study method is highly dependent on past facts rather than a risk management knowledge framework. Literature review and experts' judgment could effectively improve the research quality.

It is found that (1) the risk identification of PPP WTE incineration projects is usually employed the case study method; (2) risk identification in the process of risk assessment usually utilizes the literature review and case study methods; (3) no research is focused on PPP WTE incineration projects from the perspective of rural revitalization. In this regard, it is meaningful to investigate the risk analysis of PPP WTE incineration plants with respect to rural revitalization. The rest of the paper is organized as follows. Section 2 reviews the risk management of PPP projects, especially PPP waste-to-energy projects. Section 3 provides the overall research methodology. The risk identification of PPP waste-to-energy incineration projects is stated in Section 4. A structured questionnaire survey and the analysis is conducted in Section 5. Conclusions are drawn in Section 6.

2. Literature Review

2.1. Risk Management of PPP Projects

PPP is short for public–private partnerships, which include a variety of different forms, i.e., build–operate–transfer (BOT), design–build–finance-operate (DBFO), and private finance initiative (PFI). PPP is widely used in different sectors worldwide [49–52], i.e., transportation [53], sewage [54,55], medical service [56], education [57–59], water supply [60–64], etc. No matter the form they take, PPP projects unavoidably encounter different kinds of risks due to their huge amount of capital investment, long concession periods, complex contractual relationships and various stakeholders. Risk management of PPP projects therefore becomes dominant in academic research and practice pioneers. Risk management usually includes risk identification, risk analysis, risk treatment and risk control. In particular, PPP projects are collaborative efforts of both the public and private sectors, and thus risk allocation between them is a hot topic in risk treatment. As PPP projects last for a long concession period, there is little research on risk control as it requires long-term monitoring of projects.

In the beginning, a number of scholars put their attention on risk identification. Hood and McGarvey (2002) discussed the risks of PPP projects in the Scottish local government and stated that there exist poor risk management decisions in Scottish local authorities [65].

Grimsey and Lewis (2002) examined the contractual relationships of PPP projects and pointed out there are at least nine risks for all infrastructure projects: technical risk, construction risk, operating risk, revenue risk, financial risk, force majeure risk, regulatory/political risk, environmental risk and project default [66]. Zhang classified risks into six aspects, that is, (1) social, political and legal risk, (2) unfavorable economic and commercial conditions, (3) inefficient public procurement framework, (4) lack of mature financial engineering techniques, (5) problems related to the public sector, and (6) problems related to the private sector [40]. Case studies and interviews were commonly adopted research methods at that time. Then, a number of techniques are employed for risk identification, including DEMATEL, FISM-MICMAC, social network, etc. Liu et al. (2016) identified the critical risk factors in the tendering phase of PPP projects [67]. Zhang et al. (2019) utilized the DEMATEL method to identify the critical risks in Sponge city PPP projects [68]. Jiang et al. employed the FISM-MICMAC approach to examine significant risks and their relationships [69]. Wang et al. explored the risks of infrastructure PPP projects from the perspective of social networks [70].

Risk assessments or risk evaluations is another research topic, which employs a variety of different methods. Chan et al. (2011) designed an empirical questionnaire survey to examine the relative importance of different risk factors and analyze the risk allocation between public and private sectors [71]. Wu et al. (2017) used a fuzzy synthetic evaluation analysis method to assess straw-based power generation PPP projects [72]. Li and Wang (2018, 2019) employed a fuzzy analytic hierarchical process method and a fuzzy analytic network process to conduct the risk assessment for PPP projects in China [73,74]. Chen et al. (2020) utilized an adaptive fuzzy cognitive map to evaluate the performance of PPP projects [75]. Zhao et al. (2022) evaluated sewage treatment PPP projects in China using principal component analysis, criterial importance through intercriteria correlation, and technique for order preference by similarity to an ideal solution [55].

Risk allocation is given special attention in the circumstance of a PPP environment. Abednego and Ogunlana (2006) investigated the proper risk allocation of PPP projects for good project governance in Indonesia [76]. Ibrahim et al. (2006) identified 61 risks and analyzed the risk allocation in PPP projects in Nigeria [77]. Medda (2007) employed game theory to model the behavior of public and private sectors in PPP projects and to propose suitable risk allocation [78]. Jin and Doloi (2008) utilized transaction cost economics to interpret the risk allocation mechanism of PPP projects [79]. Ke et al. (2010, 2013) conducted a two-round Delphi survey to investigate the preferred risk allocation and misallocation in China's PPP projects [80,81]. Jin (2010) also developed a neurofuzzy decision support system to help decision-making of risk allocation in PPP projects [41]. Heravi and Hajihosseini (2012) took the Tehran–Chalus tool road as a case study to examine risk allocation in PPP projects in developing countries [82]. Li et al. (2017) examined the risk allocation of PPP projects using bargaining game theory [83]. Castelblanco et al. (2020) investigated the risk allocation in solicited and unsolicited PPP road projects [84]. Nguyen et al. (2018) utilized the content analysis method to examine the U.S. PPP highway project contracts and showed majority of risks were either transferred to the private sector or shared [85].

WTE incineration projects are one kind of infrastructure. Risk management of PPP infrastructure projects sheds light on the risk management of PPP WTE incineration projects. The widely used risk analysis methods include case studies, literature reviews and questionnaire surveys.

2.2. Risk Management for PPP WTE Incineration Projects

Though the majority of risk management for PPP projects focuses on infrastructure, there do exist a number of studies associated with risk management for PPP WTE incineration projects.

Regarding risk identification, case studies are a widely used method. Song et al. (2010) examined six international PPP WTE incineration projects and identified 10 risks including government decision-making risk, government credit risk, legal and policy risk, technical risk, contract change risk, environment risk, public opposition risk, waste supply risk, pay risk and revenue risk [45]. Xu et al. (2015) identified 21 risks associated with PPP WTE incineration projects using a literature review and case study and pointed out that the important risks are waste supply risk, environment risk, inappropriate waste disposal, payment risk and infrastructure risk [86]. Wang and Zhang (2017) identified 21 risks through a case study and pointed out the top five risks through a questionnaire survey [46], that is, public opposition, environment pollution, land acquisition & administration approval, revenue risk and government credit risk. Liu et al. (2018) analyzed 35 PPP WTE cases to obtain 18 risks and stated that high-risk ones include public opposition, environmental pollution, government decision-making, defective legal and regulatory system and waste supply [43]. Cui et al. (2020) recognized 6 critical risks from 18 ones, including public opposition, government decision-making, legal and regulatory risk, environmental pollution, lack of infrastructure and government credit risk [35].

A number of linguistic operators are utilized to conduct a risk assessment of PPP WTE incineration projects. Wu et al. (2018) selected 14 critical risks from 37 PPP infrastructure risks and 14 PPP WTE incineration projects, categorized them into four classes including construction and operation risks, macro-economic risks, legal and socio-political risks and government risks and evaluated them in a linguistic environment [87]. Luo et al. (2021) conducted a risk assessment of a PPP WTE project in China using hybrid weight methods and weighted multigranulation fuzzy rough sets [44]. Dolla and Laishram (2021) identified 22 risks in an Indian PPP WTE incineration project and used them for risk assessment [88].

It is found that (1) risk identification of PPP WTE incineration projects usually employs the case study method; (2) risk identification in the process of risk assessment usually utilizes the literature review and case study methods.

3. Research Methodology

In order to conduct a risk analysis of PPP WTE incineration projects from the perspectives of rural revitalization, this paper organized the research, as shown in Figure 2.

- Step 1: Identify the preliminary risk list of the PPP WTE incineration project through a comprehensive literature review. After reading the related journal papers, it was found that most PPP risk management papers are related to infrastructure projects rather than WTE incineration projects. 8 papers are selected as the sources of risk identification for preparing the preliminary risk list.
- Step 2: Refine the risk list through a focus group discussion with domain experts. 8 experts were invited to examine the preliminary risk list. In particular, the experts were asked to provide new risk factors.
- Step 3: Conduct a structured questionnaire survey to collect the frequency and severity of the final risk list. The questionnaire is designed on the basis of the final risk list. The designed questionnaire was distributed to the 135 stakeholders of PPP WTE incineration projects. A total of 111 questionnaires were collected. 11 records are invalid according to the filtering criteria, so a total of 100 questionnaires were verified for further analysis.
- Step 4: Analyze the risks of PPP WTE incineration projects based on the survey. The internal consistency and reliability of the survey were first tested. After that, risks were analyzed based on the survey result from the perspective of risk frequency, risk severity and overall risk impact.

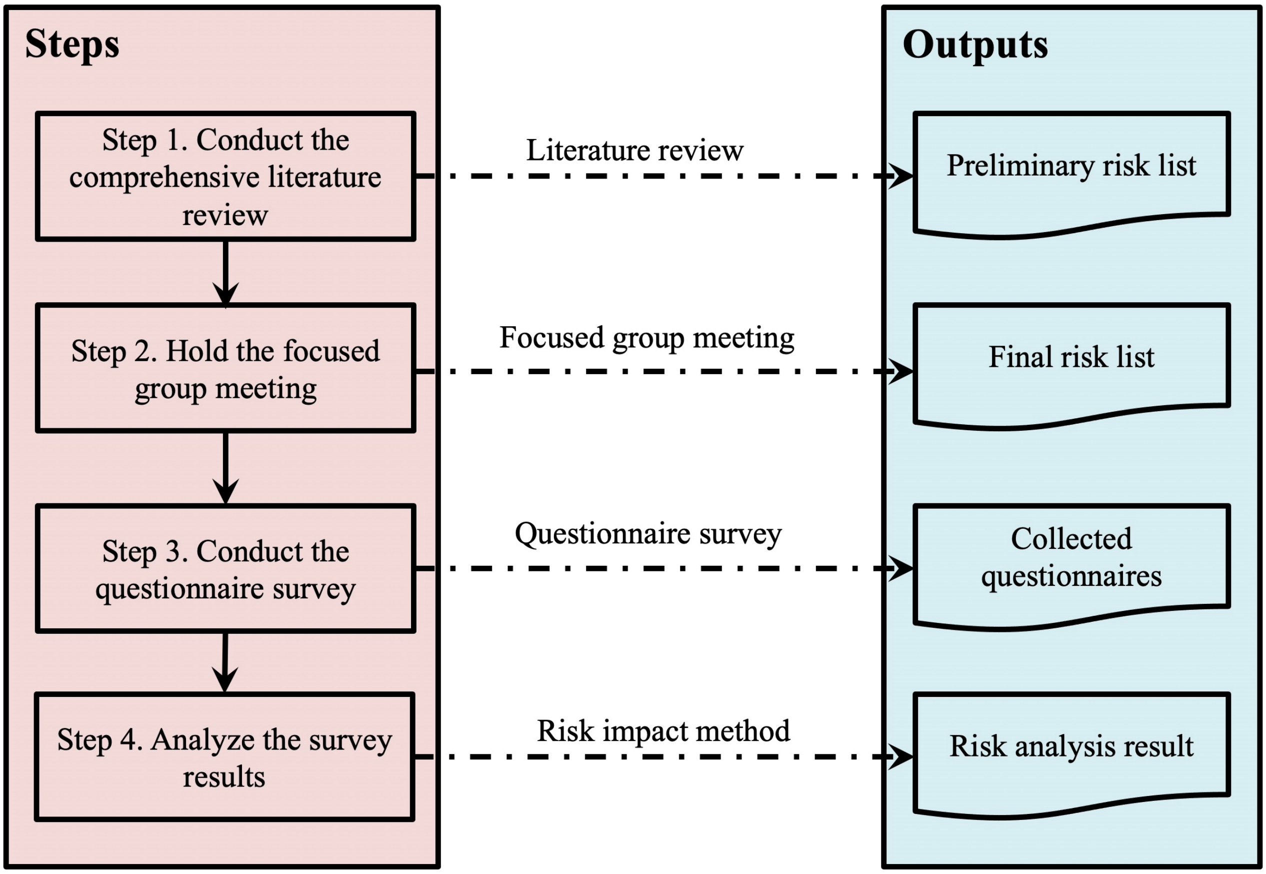

Figure 2. The overall methodology.

In order to understand the risks of PPP WTE incineration projects from the perspective of rural revitalization, the study conducted a structured questionnaire survey on the basis of the final risk list identified in Section 4. The questionnaire is divided into three parts. The first part is the basic information of the respondents. The second and third parts collect the opinions of respondents regarding the frequency and severity of the risks, respectively. Both the frequency and severity of risks are expressed through Likert's 5-level scale. Regarding the frequency of risks, 1, 2, 3, 4, and 5 represent "extremely low", "low", "fair", "high" and "extremely high", respectively. With respect to the severity of risks, 1, 2, 3, 4, and 5 represent "not serious", "fairly serious", "serious", "very serious" and "extremely serious", respectively.

4. Risk Identification of PPP WTE Incineration Projects from the Perspective of Rural Revitalization

4.1. Preliminary Risk List from Comprehensive Literature Review

As mentioned in Section 3, the preliminary risk list was obtained through a comprehensive literature review. After examining these journal papers, eight papers were chosen for detailed analysis, that is, references [35,43,45,46,86–88]. Among these papers, five papers are related to risk identification, while three papers are associated with risk assessment. A detailed analysis of these papers is provided in Section 2.2. The preliminary risk list of PPP WTE incineration projects is presented as R1~R36 in Table 1. The symbol "$\surd$" in a specific cell of Table 1 means the reference of the column includes the risk of the row directly or indirectly.

Table 1. The preliminary risk list of PPP WTE incineration projects from the literature review.

No.	Name of Risk	[45]	[86]	[46]	[43]	[87]	[35]	[44]	[88]
R01	Government decision-making	√		√	√	√	√	√	√
R02	Government credit	√	√	√	√	√	√	√	√
R03	Legal and regulatory	√	√	√	√	√	√	√	√
R04	Technical	√		√	√		√	√	√
R05	Contract change	√			√		√		√
R06	Environment	√	√	√	√	√	√	√	√
R07	Public opposition	√	√	√	√	√	√	√	
R08	Waste supply	√	√	√	√	√	√	√	√
R09	Payment risk	√	√	√	√	√	√	√	√
R10	Revenue risk	√	√	√	√	√		√	√
R11	Government intervention		√		√	√	√	√	
R12	Nationalization		√						
R13	Land acquisition		√	√					√
R14	Administrative approval		√	√					√
R15	Local infrastructure		√		√	√	√		√
R16	Inflation risk		√	√	√		√		
R17	Financing risk		√						√
R18	Construction completion		√	√				√	√
R19	Market demand		√					√	√
R20	Price change risk		√						
R21	Force majeure		√	√				√	√
R22	Organization risk		√						
R23	Construction cost overrun			√				√	
R24	Operation cost overrun			√		√	√	√	√
R25	Operation performance			√		√	√	√	√
R26	Private sector decision-making			√				√	
R27	Private sector credit			√				√	
R28	Interest rate risk			√	√		√	√	
R29	Exchange rate risk			√	√		√		
R30	Equipment risk				√		√		
R31	Safety risk				√		√		√
R32	Design risk				√		√	√	√
R33	Inadequate supervision							√	
R34	Waste collection and segregation								√
R35	Transfer risk								√
R36	Competition risk								√

4.2. Final Risk List from a Focused Group Discussion

The focused group discussion was held by eight experts with rich experience in PPP WTE incineration projects. As mentioned in Section 1, government authorities and private sectors are two important roles in the sustainable development of PPP WTE incineration projects. In this regard, three government officers and three managers from the private sector were invited to join the focused group discussion. Moreover, in order to reflect the overall knowledge framework, one associate professor from one of the top universities in China and one general manager from a PPP consulting company joined the focused group discussion. All experts have enough experience, as shown in Table 2. Regarding the PPP projects, all experts have more than five years' experience, and six experts even have more than 10 years of experience. With respect to PPP WTE incineration projects, these experts also have enough experience to perform judgments.

Table 2. The experts in the focused group discussion.

No	Institution	Qualified Background
Expert #1	Associate Professor; Top university	10 years PPP experience; 8 years PPP WTE experience
Expert #2	Manager; Private sector	10 years PPP experience; 9 PPP WTE incineration projects
Expert #3	General manager; Project company	8 years PPP experience; 8 years PPP WTE experience
Expert #4	General manager; Project company	10 years PPP experience; 5 PPP WTE incineration projects
Expert #5	Government officer	12 years PPP experience; 12 years PPP WTE experience
Expert #6	Government officer	10 years PPP experience; 5 PPP WTE incineration projects
Expert #7	Government officer	5 years PPP experience; 5 years PPP WTE experience
Expert #8	General manager; Consulting company	11 years PPP experience; 50 + PPP projects

The experts first added new risks with respect to rural revitalization. Previous studies showed the extensive risk factors associated with political risks, economic risks and technical risks. However, the social risks were not mentioned too much. The experts agreed that there are three aspects of PPP WTE incineration projects to benefit rural development.

- First, PPP WTE incineration projects could enhance local economic development. In the construction phase, the local construction industry can get benefits as PPP WTE incineration projects usually consume a substantial amount of capital investment. In the operation phase, PPP WTE incineration projects could provide tax and other financial support to local government authorities. It is denoted as R37 in Table 3.
- Second, PPP WTE incineration projects could enhance local employment. On the one hand, local people can participate in the construction of PPP WTE incineration projects during the construction phase. On the other hand, the operation of PPP WTE incineration projects requires a large number of laborers—especially skilled laborers. It not only provides more opportunities for local employment but also improves its quality. Employment is an important indicator of social influences [22,89]. It is denoted as R38 in Table 3.
- Third, PPP WTE incineration projects could improve the appearance of rural villages. They take the generated solid waste of nearby villages as the raw materials for power generation and thus reduce the storage of rural solid waste. The reduction of storage could effectively improve rural appearance. It is denoted as R39 in Table 3.

Table 3. The results of the focused group discussion.

No.	Name of Risk	Action Type
R37	Local economic development	Add
R38	Local employment	Add
R39	Rural appearance	Add
R40	Local government succession	Add
R41	Location risk	Add
R11	Government intervention	Delete
R12	Nationalization	Delete
R33	Inadequate supervision	Delete
R35	Transfer risk	Delete
R36	Competition risk	Delete

The experts were also asked to add other risks. Two new risks were proposed: one is local government succession risk, and the other is location risk.

- Local government succession risk refers to the change of leaders in local governments. In China, main government leaders usually stay in one position for around five years, while most PPP WTE incineration projects last for around 20 years. In this regard, main government leaders may change four or more times for a specific project. The new leaders may not be familiar with the projects and thus influence their normal operation. It is denoted as R40 in Table 3.

- Location risk is location selection by both public sectors and private sectors. In case of inappropriate locations, the infrastructure and logistics may be influenced dramatically. It is denoted as R41 in Table 3.

Then, the experts examined all the risks on the list. It is suggested to eliminate several risks (including R11, R12, R33, R35 and R36) as they are not suitable nowadays or duplicate with other risks.

- Government intervention (R11). This risk is usually duplicated with other ones, for example, contract change, government decision-making, etc. In this regard, it is suggested to eliminate it from the list.
- Nationalization (R12). With the development of the legal and regulatory system, it is believed that nationalization (R12) is not possible in China. In the worst case, the government authorities will purchase the projects by soliciting the agreements of the private sector.
- Inadequate supervision (R33). As PPP projects increased rapidly in the last decade, government authorities issued a lot of policies to guide their behaviors [36]. At the same time, two platforms were developed to increase the transparency of PPP projects [37,38]. Currently, inadequate supervision may not happen with a very high probability.
- Transfer risk (R35). Government authorities play a significant role in the contractual relationships with the private sector. Once the concession period reaches, it is hard for private sectors to default on the contract.
- Competition risk (R36). It is common sense that waste handling is one kind of public service and thus is the responsibility of government authorities. As PPP contracts are usually exclusive agreements, competition cannot happen between PPP ones and private ones.

Finally, the final risk list was derived to include 36 risk factors.

5. Questionnaire Survey and Risk Analysis

5.1. Questionnaire Survey

5.1.1. Sociodemographic Analysis of the Respondents

Table 4 shows the sociodemographic statistics of the respondents. The respondents are from a wide range of organizations, including government officers (11 officers accounts for 11% of all respondents), private sector (13%), project company (60%), PPP consult company (3%), and academic research (5%), etc. Among them, project company staff accounts for the majority of the respondents. The diversity of organizations could help understand the actual situation towards PPP WTE incineration projects in rural areas. With respect to age, there are 2, 37, 41 and 20 respondents falling in the 18~25, 26~35, 36~44 and 45~60 ranges, respectively. Regarding working experience in PPP projects, 50% of respondents have more than five years' experience. On the other hand, 66% of respondents participated in 1~2 projects. It indicates that PPP WTE incineration projects usually last a long time and operation staff in one company tend to stay stable. Most respondents (73%) took part in 1~2 PPP WTE incineration projects. In particular, there are three respondents involved in more than 20 projects who are from consult companies.

Table 4. Sociodemographic data of the respondents.

Category	Type	Frequency	Percentage
Affiliated organization	Government officers	11	11%
	Private sector	13	13%
	Project company	60	60%
	PPP consult company	3	3%
	Academic researcher	5	5%
	Others	8	8%
Age	18~25	2	2%
	26~35	37	37%
	36~44	41	41%
	45~60	20	20%
PPP working experience (Unit: Year)	Less than 2 years	13	13%
	2~4 years	37	37%
	5~10 years	36	36%
	11~15 years	11	11%
	More than 15 years	3	3%
Number of PPP projects involved	1~2	66	66%
	3~5	21	21%
	6~10	7	7%
	11~20	3	3%
	More than 20	3	3%
Number of PPP WTE incineration projects involved	1~2	73	73%
	3~5	14	14%
	6~10	9	9%
	11~20	1	1%
	More than 20	3	3%

5.1.2. Reliability and Validity Test of the Questionnaire Survey

The reliability and validity of 100 records were tested. Cronbach's alpha was used to test the reliability of the survey data. After the calculation by SPSS, the Cronbach's alpha of this survey is 0.930; therefore, the reliability performance is excellent. At the same time, the validity of the survey was tested by KMO and Bartlett's Test of Sphericity. Table 5 shows that (1) KMO is 0.936, which is greater than 0.9; (2) the significance of Bartlett's Test of Sphericity is 0, less than 0.05; (3) the test indicates the questionnaire has structural validity. In view of the tests, the reliability and validity of this survey are verified.

Table 5. Reliability and validity test of the questionnaire survey.

Item	Cronbach's Alpha	KMO	Bartlett's Test of Sphericity		
			Approximate Chi-Square	Degree of Freedom	Significance
Risk frequency	0.978	0.936	4121	630	0.000
Risk severity	0.980	0.914	4812	630	0.000

5.2. Analysis of Questionnaire Survey Results

5.2.1. Analysis Method of Questionnaire Survey

In the survey, the range of risk frequency is between 2.16 and 3.32. The difference between the maximum and minimum values is 1.16, which indicates the respondents show a certain degree of consensus on risk frequency. Similarly, the difference between the maximum (2.70) and minimum (1.78) of risk severity is 0.92, which shows a higher degree of consensus on risk severity. The data is ready for further analysis. In this study, risk frequency and risk severity are utilized to determine risk ranking. As mentioned before, both risk frequency and risk severity are expressed as an integer from 1 to 5. The mean score ranking [62,90] is utilized to calculate the average risk frequency (P) and average risk severity by Equations (1) and (2), respectively, as

$$P_i = \frac{\sum_{j=1}^{M} p_{ij}}{M}, \quad (1)$$

$$S_i = \frac{\sum_{j=1}^{M} s_{ij}}{M}, \quad (2)$$

where P_{ij} is the j-th respondent's score on the frequency of the i-th risk; S_{ij} is the j-th respondent's evaluation of risk severity of the i-th risk; P_i is the average frequency of the i-th risk; S_i is the average score on risk severity of the i-th risk; i = 1, . . . 36; and M is the total number of respondents and equal to 100.

The risk significance index (RSI) [35] is calculated by:

$$RSI_i = P_i \times S_i, \quad (3)$$

where RSI_i is the risk significance index of the i-th risk.

Then, the risk impact (RI) [35] is derived as:

$$RI_i = \sqrt{RSI_i}, \quad (4)$$

where RI_i is the risk impact of the i-th risk.

5.2.2. Analysis from the Perspective of Risk Frequency

Table 6 presents the calculation results using Equations (1)–(4). The third and fourth columns of Table 6 show the risk frequency and the corresponding ranking, respectively. A detailed analysis of the top 10 risks regarding risk frequency is as follows:

- The top three risks regarding risk frequency are rural appearance, local employment and local economic development with 3.32, 3.26, and 3.15, respectively. It shows that all three values are more than three, while risk frequencies of other factors are lower than three. It shows that the respondents are confident in PPP WTE incineration projects for rural development.
- The payment risk follows as the fourth. It is one of the biggest concerns from the perspective of the private sector. In reality, delayed payment often occurs due to the financial constraints of many local governments.
- The fifth and sixth are construction cost overrun and operation cost overrun, respectively. Since the financial feasibility analysis of a typical PPP WTE incineration project is usually submitted before its start, the costs may increase due to the price increase of raw materials, human resources, etc.
- Local government succession and price change rank seventh. Due to the long concession periods of PPP WTE incineration projects, a lack of familiarity or understanding of projects by local government leaders may lead to difficulties in operation. In addition, on October 20, 2020, MOF, NDRC and NEA issued a supplementary notice. It states that the reasonable utilization hours of biomass power generation in the whole life cycle are 82,500 h and the financial subsidy will be stopped after 15 years from the date of grid connection no matter whether the subsidy hours reached 82,500 [91].
- The ninth risk is waste supply. Waste for the PPP WTE incineration project comes from the surrounding towns and villages and depends on the collection and transportation to a relatively high degree.
- The 10th risk is project revenue, which is the key to ensuring the continuous operation of the PPP WTE incineration project. It will be affected by a variety of uncertain factors, so the probability of occurrence will also increase.

Table 6. Overall ranking of risks in PPP WTE incineration projects from the perspective of rural revitalization.

No.	Risk	Risk Probability		Risk Severity		RSI	RI	RI Ranking
		Probability	Ranking	Severity	Ranking			
R39	Rural appearance	3.32	1	2.40	9	7.97	2.82	1
R09	Payment risk	2.93	4	2.70	1	7.91	2.81	2
R38	Local employment	3.26	2	2.32	20	7.56	2.75	3
R37	Local economic development	3.15	3	2.29	22	7.21	2.69	4
R40	Local government succession	2.80	7	2.51	4	7.03	2.65	5
R24	Operation cost overrun	2.83	6	2.46	6	6.96	2.64	6
R08	Waste supply	2.75	9	2.51	4	6.90	2.63	7
R23	Construction cost overrun	2.86	5	2.38	10	6.81	2.61	8
R10	Revenue risk	2.72	10	2.46	6	6.69	2.59	9
R20	Price change risk	2.80	7	2.35	13	6.58	2.57	10
R01	Government decision-making	2.53	16	2.58	2	6.53	2.55	11
R02	Government credit	2.49	21	2.53	3	6.30	2.51	12
R14	Administrative approval	2.67	11	2.34	15	6.25	2.50	13
R25	Operation performance	2.67	11	2.33	17	6.22	2.49	14
R13	Land acquisition	2.53	16	2.45	8	6.20	2.49	15
R07	Public opposition	2.60	14	2.36	12	6.14	2.48	16
R41	Location risk	2.65	13	2.31	21	6.12	2.47	17
R17	Financing risk	2.58	15	2.37	11	6.11	2.47	18
R31	Safety risk	2.50	20	2.35	13	5.88	2.42	19
R26	Private sector decision-making	2.49	21	2.33	17	5.80	2.41	20
R27	Private sector credit	2.45	24	2.33	17	5.71	2.39	21
R18	Construction completion	2.53	16	2.24	25	5.67	2.38	22
R05	Contract change	2.49	21	2.23	27	5.55	2.36	23
R06	Environment	2.29	29	2.34	15	5.36	2.31	24
R16	Inflation risk	2.52	19	2.10	30	5.29	2.30	25
R32	Design risk	2.27	31	2.25	23	5.11	2.26	26
R21	Force majeure	2.28	30	2.24	25	5.11	2.26	27
R34	Waste collection and segregation	2.45	24	2.07	32	5.07	2.25	28
R19	Market demand	2.37	27	2.13	29	5.05	2.25	29
R03	Legal & regulatory	2.24	33	2.25	23	5.04	2.24	30
R28	Interest rate risk	2.44	26	1.98	34	4.83	2.20	31
R22	Organization risk	2.30	28	2.08	31	4.78	2.19	32
R04	Technical risk	2.16	35	2.17	28	4.69	2.16	33
R15	Local infrastructure	2.26	32	1.98	34	4.47	2.12	34
R30	Equipment risk	2.16	35	2.06	33	4.45	2.11	35
R29	Exchange rate risk	2.22	34	1.78	36	3.95	1.99	36

5.2.3. Analysis from the Perspective of Risk Severity

The fifth and sixth columns of Table 6 show the risk severity and the corresponding ranking, respectively. The average risk severity is 2.29, which is low. It reflects that PPP WTE incineration projects become normalization under supervision and thus the overall severity is low. A detailed analysis of the top 10 risks regarding risk severity is as follows:

- Regarding risk severity, the risks with high ranks are associated with the public sector. The payment risk, government decision-making, government credit and local government succession are ranked first, second, third, and fourth, respectively. It shows that government behaviors have significant impacts on PPP WTE incineration projects. In particular, subsidies for power generation for PPP WTE incineration projects are usually paid by government authorities. If the payment is delayed or canceled due to various reasons, the operation and development of projects will be seriously affected.
- Another fourth risk is waste supply risk. In the PPP WTE incineration projects, the subsidy is calculated by the amount of waste handled. Therefore, the waste supply risk directly affects revenue and endangers the daily operation of projects.

- Revenue risk and operating cost overrun rank sixth. For a specific PPP WTE incineration project, sustainable development depends on two important aspects: one is revenue, and the other is cost.
- The eighth is land acquisition risk. It occurs at the very beginning of projects and directly leads to the delay or cancellation of projects, so its severity is high. However, as the questionnaire is distributed to PPP WTE incineration projects in rural areas, the severity of land acquisition is lower than that of Wang and Zhang (2017) [46].
- The ninth is rural appearance. PPP WTE incineration projects can effectively absorb household waste in rural areas. Otherwise, the waste in rural areas will occupy farmlands and cause environmental pollution.
- The 10th risk is construction cost overrun, which could lead to extending the concession period if the contract has a flexible term clause.

5.2.4. Analysis from the Perspective of Overall Risk Impact

According to the assessment of its occurrence probability and severity, the overall risk impact and the corresponding ranking are shown in the eighth and ninth columns of Table 6, respectively. The top 10 risks are rural appearance, payment risk, local employment, local economic development, local government succession, operation cost overrun, waste supply, construction cost overrun, revenue and price change risk.

- Among these risks, three ones are proposed by the focused group discussion, that is, rural appearance, local employment and local economic development. The survey results confirmed that PPP WTE incineration projects can effectively promote local development in rural areas.
- Another observation is that government authorities have a significant impact on PPP WTE incineration projects. On the one hand, these projects are highly dependent on the subsidies provided by government authorities (payment risk). On the other hand, the sustainable development of projects requires the support of local government authorities.
- Economic risks are of great concern. PPP WTE incineration projects are the collaborative efforts of both government authorities and private sectors. The objective of government authorities is the proper handling of solid waste with a huge amount of capital investments and high management skills. However, the objective of the private sector is a reasonable rate of return on investments. In this regard, economic risks are important for both government authorities and private sectors.
- Public opposition is not considered a significant risk. Traditionally, it is regarded as the most critical risk in previous studies [35,46] as WTE incineration projects are locally unwanted land use facilities (LULU) [92].

5.3. Analysis of Risk Categories

These factors could be classified according to their sustainable attributes, that is, environmental risks, economic risks and social risks. In particular, some risk factors may influence more than one aspect as shown in Figure 3. For example, government decision-making risk (R01) can impact all three kinds of attributes. In all categories, economic risks have the largest number (13) of risk followed by social, economic and environmental risks (10).

Table 7 presents the average RIs of different risk categories. Social risks are considered the most important for PPP WTE incineration projects in rural areas followed by social and economic risks and social and environmental risks. Economic risks have the largest number of risks and rank fourth. The preference of three attributes would be social, economic and environmental risks.

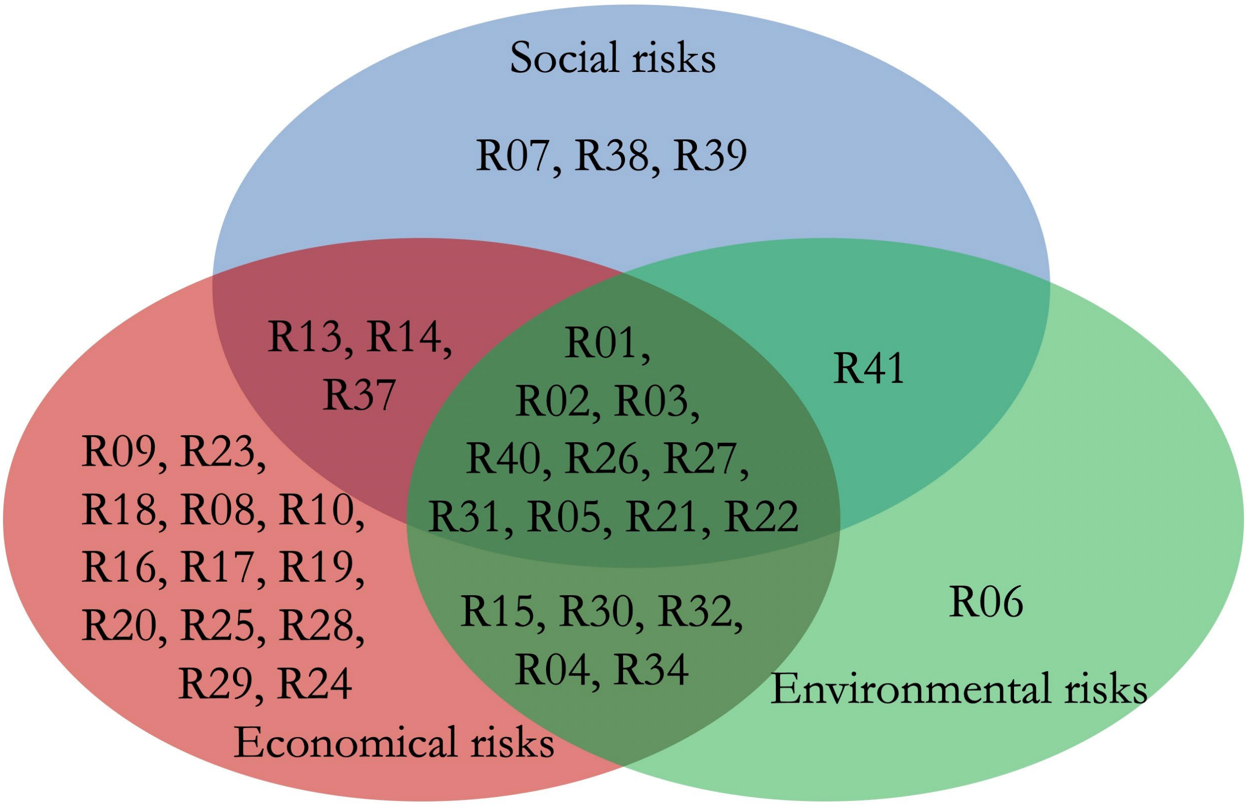

Figure 3. Risk factors with respect to sustainable development of PPP WTE incineration projects.

Table 7. The average RI of different risk categories.

No.	Number of Risks	Average RI	Ranking
Social risks	3	2.68	1
Social and economic risks	3	2.56	2
Social and environmental risks	1	2.47	3
Economic risks	13	2.46	4
Social, economic and environmental risks	10	2.40	5
Environmental risks	1	2.31	6
Economic and environmental risks	5	2.18	7
Total	36	2.43	

6. Conclusions

More and more PPP WTE incineration projects are being deployed in rural areas of China. These projects not only bring a huge amount of capital investment and management skills but also accelerate local rural development. Rural development is the core of rural revitalization. However, PPP WTE incineration projects usually last for long periods, involve many stakeholders and engage complex contract relationships; therefore, risk management becomes a significant challenge for both government authorities and the private sector. This study investigates the risk analysis of PPP WTE incineration projects from the perspective of rural revitalization.

- An extensive list of 36 risk factors was obtained through a comprehensive literature review and focused group discussion with eight experts. The literature review identified 36 risks as the preliminary risk list. The focused group discussion provided five new risk factors and eliminated five inappropriate risk factors. The systematic process could improve the completeness and accuracy of previous risk identification methods including case studies and literature reviews.

- A structured questionnaire survey was conducted to collect opinions regarding risk frequency and risk severity. A total of 100 valid questionnaires were collected. In particular, project staff are from PPP WTE incineration projects in rural areas. The research could get the options of related stakeholders from the perspective of rural revitalization.
- Survey results were analyzed with respect to risk frequency, risk severity, risk impact and risk category. The top 10 risks were examined in detail. It was found that (1) PPP WTE incineration projects in rural areas do effectively accelerate the local rural development through improving rural appearance, enhancing local employment and promoting local economic development; (2) government authorities play a significant role in the success of PPP WTE incineration projects; and (3) the risk preference of their sustainable development is social, economic and environmental risks.

The survey shows the positive impacts of PPP WTE incineration projects built in rural areas. In this regard, government authorities could adopt more PPP WTE projects to meet the ever-increasing solid waste. It could not only significantly reduce the volume of solid waste but also provide renewable energy. In addition, as the social aspects are proven to be the most important for PPP WTE incineration projects, it is crucial for both government authorities and private sectors to enhance the local employment and local rural appearance, etc. With the increasing PPP WTE incineration projects, it is meaningful to investigate the sorting of solid waste, logistics of waste transportation, and economic feasibility of PPP WTE incineration projects, etc.

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List of Main Abbreviations

WTE	Waste-to-energy
PPP	Public-private partnership
FIT	Feed-in tariff
MOF	Ministry of Finance
NDRC	National Development and Reform Commission
TGC	Tradable green certificate
NCCPC	National Congress of the Communist Party of China
CCCP	Central Committee of the Communist Party
SC	State Council
NEA	Nation Energy Administration
RSI	Risk significance index
RI	Risk impact

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