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Research Article

Identification of Risk Factors Affecting PPP Waste-to-Energy Incineration Projects in China: A Multiple Case Study

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Waste-to-energy (WTE) incineration technologies are considered an effective solution for sustainable and efficient municipal solid waste (MSW) disposal in China, and the public-private partnership (PPP) arrangement has been widely used to construct and operate WTE incineration projects. However, PPP WTE incineration projects in China are affected by numerous risks due to the long concession period, various participants, and other factors commonly involved in PPPs, resulting in a number of failures. In light of the pivotal role that risk identification, analysis, and response play in the successful development of PPP WTE incineration projects, this paper presents a multiple case study to identify the risk factors involved in China by drawing on experience from the real-life risk events of 35 PPP WTE incineration plants. 18 risk factors are identified; the most critical of which being public opposition risk, environmental pollution risk, government decision-making risk, a defective legal and regulatory system, and MSW supply risk. The results of the study provide a solid foundation for the future risk analysis, risk allocation, and risk response of PPP WTE incineration projects, and shed light on performance improvement of the PPP WTE incineration projects as well as the development of the PPP WTE industry in China.

1. Introduction

The amount of municipal solid waste (MSW) is constantly increasing in China because of its rapid development of urbanisation and industrialisation in the past three decades and continuous improvement of resident living standards. The annual amount of MSW generated reached 203.6 million tonnes in 2016 [1] and is expected to expand to 220 million tonnes by 2020 [2]. The sharply increased in MSW generation over the years puts pressure on such existing MSW disposal methods such as landfill and compost and resulted in a dilemma of "garbage siege" [3].

Incineration is considered the best way to treat the MSW due to low resource consumption, obvious physical volume reduction, less secondary pollution, and energy-recovery [4–6]. Consequently, waste-to-energy (WTE) technology has developed rapidly to provide an effective solution for government to alleviate the pressure of MSW disposal in past decades. WTE incineration in China has developed rapidly since 1988, when Shenzhen built the first WTE plant. According to statistics from the National Bureau of Statistics of China, incinerated MSW increased from 3.70 million tonnes in 2003 to 73.79 million tonnes in 2016, with the number of incineration plants increasing from 47 to 249 over the same period [1, 7].

Meanwhile, subject to budget constraints, lack of management capacity, and other factors, it is difficult for the government to construct and operate high-investment, long-term WTE incineration projects alone. To address the increasing need for WTE facilities, the public-private partnership (PPP) arrangement has been widely used to construct and operate WTE incineration projects, taking advantage of the innovation, know-how, flexibility, and financing provided by the private sector [8, 9]. In China, more than 70% of WTE incineration projects are now operated and supervised by PPPs, and 108 PPP WTE incineration projects with a total

investment of CNY 489 billion were deployed from 2012 to 2016 [8, 10].

However, due to the long concession period, involvement of various participants, external uncertainties, and other reasons, PPPs in the WTE incineration industry face more risks than traditional public projects [11–13], which affect their performance and hinder the application of WTE incineration technologies in the MSW disposal industry. In fact, ineffective risk management in the PPP WTE industry has resulted in failure of many incineration projects to reach their expected performance [14, 15]. According to risk management theory, risk identification is the basis of risk analysis and response and is crucial to the performance of risk management [16, 17]. It is therefore essential for both government and WTE private sector investors to have a clear understanding on the risks involved in PPP WTE incineration projects and to establish suitable responsive strategies accordingly.

Nevertheless, although there is ample literature concerning PPP risk identification and analysis, very little is related to the identifications of risk factors affecting PPP WTE incineration projects. Most PPP studies have been conducted to identify risk factors in such other industries as transportation [18], water supply and treatment facilities [19], energy facilities [20], and medical facilities [21]. In addition, the identified critical risk factors of PPP WTE incineration projects vary significantly between countries because of their unique social-economic environments, policies, and regulations [14, 22]. In China, Song et al. [4] and Xu et al. [23] have identified the critical risk factors affecting PPP WTE projects through case studies. However, the cases involved are insufficiently representative to reflect the status of China's PPP WTE industry because their risk events occurred before 2012, when the central and local governments introduced a series of new policies and regulations related to the PPP WTE industry [24].

In response, we conducted a multiple case study to identify the risk factors affecting PPP WTE incineration projects in China over the past decade. The results pave the way for the risk analysis, allocation, and response of PPP WTE incineration projects and are expected to shed light on their performance improvement as well as the development of the PPP WTE industry throughout the country.

2. Research Methods

The research methods used in this study comprise a comprehensive literature review and multiple case studies. The flow of the overall research framework is shown in Figure 1.

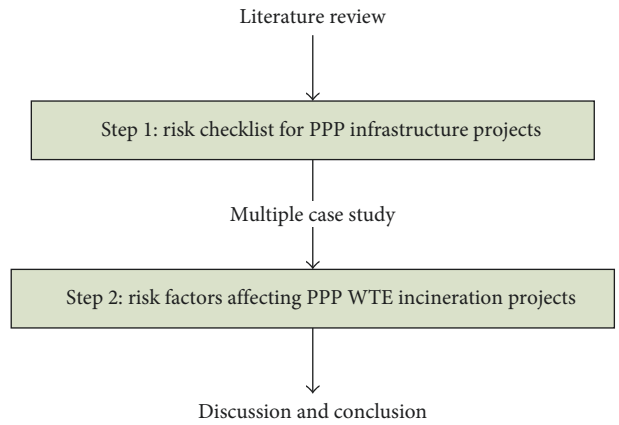

Figure 1: Overall research framework.

2.1. Literature Review. As the most commonly used method of risk identification, risk checklists depend on historical data and experience to list the risk factors of similar projects in a logical order [25]. Accordingly, the literature review provides an auxiliary method of building a risk checklist favoured in many studies [26–29] and is thus conducted here to identify the general risks involved in China PPP WTE incineration projects.

The Web of Science was used for the literature research because of its comprehensive coverage of journals worldwide. To address the local literature, the *Journal of Engineering Management* (in Chinese), *Construction Economics* (in Chinese), *Journal of Civil Engineering and Management* (in Chinese) and *Project Management Technology* (in Chinese) were chosen via the China National Knowledge Infrastructure (CNKI) database because they are the most widely recognised construction management Journals in China.

The acronym "PPP," which is used to specifically represent the noun "public-private partnerships," is mentioned in the literature in a variety of forms [2, 30], such as public-private partnerships (PPP), build-operate-transfer (BOT), private finance initiative (PFI), and design-build-finance-operate (DBFO). Therefore, in order to ensure integrity and accuracy, a keyword search process was conducted using the schema of TITLE-ABS-KEY ("public private partnership" OR "build operate transfer" OR "private finance initiative" OR "design build finance operate" OR "PFI" OR "BOT" OR "PPP" OR "DBFO") and TITLE-ABS-KEY ("risk"). From the literature retrieved in this way from selected databases or journals, articles with clear figures, tables, or text descriptions of the identified risk factors were chosen for further content analysis. This involved a total of 54 articles, including 16 Chinese articles and 38 English articles.

The most simple and effective method of identifying risk factors is to establish a risk checklist [31]. This was created in three steps: (1) the risk factors related to PPP infrastructure projects were identified through a comprehensive literature review; (2) these were carefully examined by deleting the inherent risk factors of some categories of PPP projects, for example, the safety risk in PPP highway projects caused by overload and combining risk factors with the same meanings but using different terms; and (3) the risk checklist was established with a clear hierarchical structure through a synthesised risk classification drawn from the literature.

Based on the comprehensive literature review, the risk checklist composed of 54 risk factors was established (Table 1). This follows the classification method of PPP risk factors proposed by Li et al. [26], where the risk factors are divided

Table 1: Risk checklist of PPP projects.

Risk level	Risk categories	Risk factors
Macrolevel risks	1. Political risks	1. Government decision-making risk
		2. Government credit risk
		3. Government behaviour risk
		4. Unstable government
		5. Expropriation or nationalisation of assets
		6. Strong political opposition/hostility
	2. Legal risks	7. Policy risk
		8. Defective legal and regulatory system
		9. Industrial regulatory change
	3. Macroeconomic risks	10. Interest rate volatility
		11. Inflation risk
		12. Foreign exchange risk
		13. Influential economic events
		14. Poor financial market
	4. Social risks	15. Public opposition risk
		16. Market demand risk
	5. Natural risks	17. *Force majeure* risk
		18. Weather/geological condition
		19. Environmental risk
Mesolevel risks	6. Project selection risks	20. Land acquisition risk
		21. Delay in project approvals and permits
	7. Project finance risks	22. High finance costs
		23. Project financial attractiveness
		24. Availability of finance
	8. Design risks	25. Inadequate competition for tender
		26. Design change
		27. Design deficiency
	9. Construction risks	28. Construction cost overrun
		29. Construction delay
		30. Materials/equipment procurement risk
		31. Poor-quality workmanship
	10. Technical risks	32. Contract change risk
		33. Subcontractors or suppliers risk
		34. Technological backwardness
		35. Unproven technology
	11. Operational risks	36. Revenue and cost risk
		37. Low productivity
		38. Insufficient operation capacity
		39. Unreasonable concession period
		40. Payment risk
		41. Residual value risk
		42. Lack of supporting infrastructure
		43. Frequent maintenance
		44. Equipment risk
		45. Safety risk
		46. Environmental pollution risk
Microlevel risks	12. Relationship risks	47. Organisation and coordination risk
		48. Inadequate experience in PPP
		49. Inadequate distribution of risks
		50. Inadequate distribution of authority
		51. Differences in working method
		52. Lack of commitment
	13. Third party risks	53. Third party tort and compensation risk
		54. Staff crises

into three levels, that is, macrolevel, mesolevel, and microlevel. According to Li et al. [26], macrolevel risks refer to the risks outside the project, mesolevel risks refer to the risks within the project, and microlevel risks refer to the risks of the relationship between stakeholders.

2.2. Multiple Case Studies. The present study aims to identify the "what" and "how" risk factors affecting PPP WTE incineration projects in China. Case studies are appropriate to answer such questions [32]. Meanwhile, PPP WTE incineration projects are still in their infancy in China and

Table 2: Descriptive statistics of the cases.

Profile	Category	Frequency
Location	Eastern China	21 (60%)
	Central China	8 (22.86%)
	Western China	6 (17.14%)
Operation time	Before 2006	10 (28.57%)
	2007–2012	12 (34.29%)
	2013–2017	6 (17.14%)
	Not placed in operation	7 (20%)
Total investment (CNY 100 million)	1–5	25 (71.43%)
	5–10	6 (17.14%)
	≥10	4 (11.43%)
Design capability (tonnes/day)	500–1000	18 (51.43%)
	1000–2000	15 (42.86%)
	2000–3000	2 (5.71%)
Incineration technology	Grate furnace	20 (57.14%)
	Fluidised bed	13 (37.14%)
	Pyrolysis furnace	2 (5.71%)
Current status	Cancelled	5 (14.29%)
	In redecision-making processes	1 (2.86%)
	Under construction	1 (2.86%)
	Placed in operation	26 (74.29%)
	Closed before scheduled closure date	2 (5.71%)

relevant studies are limited. For a new or insufficiently researched field, case studies are the preferred method [33]. Moreover, a single case study is contextually stronger and is not conducive to summarising general rules and promoting the research results [34]. As a result, a variety of case studies are used to provide a range of contexts. The flow of the multiple case studies comprises the following four steps:

(1) *Determining Standards for Case Selection*: in order to fully reflect the current status of China's WTE industry and to ensure the comprehensiveness and representativeness of the cases, the criteria for case selection are as follows: (1) the WTE incineration projects are operated by PPP arrangement, such as BOT and DBFO; (2) risk events significantly that affect their performance occurred during the project lifecycle; and (3) except for some typical and significant cases, the risk events involved occurred after 2012.

(2) *Case Selection and Data Collection*: the systematic analytic process for case selection followed [35]. First, a wide range of sizable samples of actual WTE incineration plants that were heavily affected by the occurrence of a variety of risk events were collected from the literature, research reports, newspapers, and the Internet. Second, a total of 35 cases, which is far more than the usual requirement for multiple case studies [33], were selected as study cases to identify the critical risk factors by using the criteria for case selection determined above. Third, detailed information relating to these selected cases was collected from the Internet, industrial reports, media, academic literature, and other relevant materials, and a desk research of collected data was conducted to prepare materials for the upcoming content analysis. Table 2 provides details of the cases.

(3) *Identifying Risk Factors through Content Analysis*: as an observational research method to evaluate the symbolic content of all forms of materials, either qualitative or quantitative content analysis is frequently used to identify the major facets of a set of data [36]. Thus, content analysis was carried out to identify the risk factors appearing in each of selected cases by utilizing the preferred risk checklist established from the literature review.

(4) *Verifying the Identified Risk Factors by Expert Interview*: interviews with a preestablished team of experts were conducted to verify the appropriateness and comprehensiveness of the identified risk factors. The team consists of three experts with different WTE industry backgrounds—a Hangzhou government-related WTE industry official, a senior manager from a WTE incineration plant (Hangzhou Green Energy Environmental Protection Power Co., Ltd), and a researcher related to WTE implementation.

3. Results

The identified risk factors seriously affecting the performance of each case are summarised in Table 3.

Table 4 summarises the frequency of the risk factors identified in the case studies, divided into high-, medium-, and low-frequency risks. The high-frequency risks (appearing in at least 10 of the 35 cases) comprise public opposition risk, environmental pollution risk, government decision-making risk, defective legal and regulatory system, and MSW supply risk and may heavily affect the performance and development of the WTE incineration industry in China. Medium-frequency risks refer risk factors of the frequency from 4 to 10,

Table 3: PPP WTE incineration cases and risk factors.

Number	Project	Operation time	Risk events	Identified risk factors
1	Ningbo Fenglin WTE incineration project	2001	The supplied MSW could not be burned immediately due to containing a high level of water. Insufficient MSW treatment facilities led to environmental pollution. The residents suggested the government to close the project, which the government promised to do at the beginning of 2014. Finally, the project was closed in June 2014, although there was still a 14-year concession period remaining	(i) MSW supply risk (ii) Environmental pollution risk (iii) Lack of supporting infrastructure (iv) Government credit risk
2	Zhengzhou Xingjin WTE incineration project	2000	Due to insufficient MSW supply, the incinerators had to be used alternately. The operator was suspected of using coal instead of MSW to increase production. The PPP company suffered heavy losses between 2004 and 2005. The transportation cost of MSW was then increased because a new toll station was set up between the CBD and the plant. In 2013, local residents complained that the neighbouring environment was polluted by MSW and wastewater	(i) MSW supply risk (ii) Defective legal and regulatory system (iii) Revenue and cost risk (iv) Government decision-making risk (v) Public opposition risk (vi) Environmental pollution risk
3	Anhui Wuhu WTE incineration project	2003	The on-grid electricity price of waste incineration was so low that the plant suffered heavy losses from 2003 to 2005. The supply of MSW was insufficient from 2003 to 2004	(i) Policy risk (ii) Revenue and cost risk (iii) MSW supply risk
4	Chongqing Tongxing WTE incineration project	2005	Both the quantity and the quality of MSW supplied did not reach the expected standard. There was no municipal sewage pipe network on both sides of the main road, which caused serious environmental pollutions. The owners had signed a new contract beyond the concession contract for their own interests. A safety accident occurred because of the poor design of the transportation vehicles. The MSW disposal fee was not paid on time, increasing the financial pressure of the PPP operator in 2006	(i) MSW supply risk (ii) Lack of supporting infrastructure (iii) Environmental pollution risk (iv) Defective legal and regulatory system (v) Safety risk (vi) Design deficiency (v) Payment risk
5	Kunming Wuhua WTE incineration project	2008	Due to unclear regulations and unsuitable technologies, the private investors from the U.S. decided to withdraw their investment in 2006. The supply of MSW was inadequate so that machines were standing idle. The MSW disposal charge was delayed from 2008 to 2013	(i) Unproven technology (ii) Policy risk (iii) Contract change risk (iv) MSW supply risk (v) Payment risk

Table 3: Continued.

Number	Project	Operation time	Risk events	Identified risk factors
6	Zhongshan Center zutuan WTE incineration project	2006	Both the quantity and the quality of the MSW supplied did not reach the expected standard and some equipment was damaged. In 2006, the incinerators were shut down temporarily to clean up the remains caused by unsuitable MSW, which led to heavy losses. In 2014, due to existing environmental pollution, the plant faced strong opposition from the local community	(i) MSW supply risk (ii) Equipment risk (iii) Environmental pollution risk (iv) Public opposition risk
7	Xuchang Tianjian WTE incineration project	2004	A financial loss emerged in 2008 due to rising coal prices and the low price of electricity generated from the WTE incinerators. The quality of the MSW supplied did not reach the expected standard, and some equipment was damaged. In 2015, 2016, and 2017, the project was fined by local governments for heavy environmental pollution. With rapid urbanisation, increasing numbers of urban residents were living around the originally desolate WTE incineration plant. Due to outdated technologies, it was difficult for the plant to meet China's current emission standards. The plant was finally reconstructed on another site in 2017	(i) Revenue and cost risk (ii) Policy risk (iii) MSW supply risk (iv) Equipment risk (v) Technological backwardness (vi) Environmental pollution risk (vii) Defective legal and regulatory system (viii) Government decision-making risk
8	Beijing Liulitun WTE incineration project	—	The construction site chosen by the local government was located windward of the CBD and close to the water-source protection area of Beijing. The government was trying to conceal risk issues, seriously affecting public credibility. The local residents opposed the project due to potential environmental and health impacts. The project was finally suspended in 2007	(i) Government decision-making risk (ii) Public opposition risk (iii) Government credit risk (iv) Environmental pollution risk
9	Jiangsu Wujiang WTE incineration project	2009	The EIA was insufficient and was considered fake by the local residents. The construction of the project did not stop despite public opposition. Local residents gathered to protest, and the project was finally cancelled in 2009	(i) Government decision-making risk (ii) Public opposition risk
10	Shenzhen Pinghu WTE incineration project	2005	The actual height of the chimney did not match the requirements of the original design documents, resulting in poisonous gas diffusion. The actual situation was not consistent with the promised technical standards, and the equipment for environmental protection did not work for nearly 3 years. In 2009, the local residents opposed the project due to serious environmental pollution involved	(i) Design deficiency (ii) Public opposition risk (iii) Environmental pollution risk (iv) Technological backwardness (v) Equipment risk

Table 3: Continued.

Number	Project	Operation time	Risk events	Identified risk factors
11	Guangzhou Likeng WTE incineration project	2005	In 2010, an explosion occurred in the incinerator causing five people to be injured. The plant was then asked to stop for rectification and reformation. Environmental pollution caused by garbage truck leakage frequently occurred. In 2012, the plant was fined because of the incomplete incineration of MSW	(i) Safety risk (ii) Environmental pollution risk (iii) Defective legal and regulatory system
12	Wuxi Xidong WTE incineration project	2011	The government's publicity for the project was insufficient. In 2011, the residents opposed the plant due to black smoke and a pungent odour. The 90% completed project finally failed and suffered great losses	(i) Public opposition risk (ii) Government decision-making risk (iii) Environmental pollution risk
13	Guangxi Laibin WTE incineration project	2008	The MSW supply was seriously insufficient in 2008. During 2008–2010, production costs increased significantly due to rising coal prices and a defective subsidy mechanism. In 2011, the plant was closed because of maintenance problems	(i) MSW supply risk (ii) Policy risk (iii) Revenue and cost risk
14	Guangdong Huizhou WTE incineration project	2007	Some outdated technologies and second-hand equipment were found to be used in this plant in 2013, resulting in environmental pollution. The project was then opposed by local residents and stopped operation. Some corruption occurred in the bidding process. Relevant monitoring data of the plant were not disclosed in time. The local government finally terminated the contract and started a new one in 2013	(i) Technological backwardness (ii) Equipment risk (iii) Defective legal and regulatory system (iv) Government behaviour risk (v) Public opposition risk (vi) Environmental pollution risk (vii) Contract change risk (viii) Revenue and cost risk
15	Shanghai Jiangqiao WTE incineration project	2003	The EPA did not positively answer the questions raised by hearing representatives. The residents protested over the project's expansion in 2009. In 2013, a major explosion happened because of the lack of on-site safety management and a third party breaking operation rules	(i) Public opposition risk (ii) Government decision-making risk (iii) Safety risk (iv) Defective legal and regulatory system
16	Hanyang Guodingshan WTE incineration project	2012	The plant was constructed in a densely populated area and separated from an existing medical waste incineration plant by a wall. The residents protested due the project's potentially hazardous impact. In 2013, the project was asked to stop for a variety of reasons, that is, starting to operate without authorisation, inadequate environmental protection facilities, and the uncompleted resettlement of the surrounding residents. However, forced by the pressure of garbage siege, the project was reoperated in 2014	(i) Government decision-making risk (ii) Environmental pollution risk (iii) Public opposition risk (iv) Defective legal and regulatory system

Table 3: Continued.

Number	Project	Operation time	Risk events	Identified risk factors
17	Wenzhou Leqing WTE incineration project	2013	The decision-making procedure was questioned by the local residents because most of them were not informed during both the environmental impact assessment process and the planning and construction approval process. To prevent the expansion of the project, several protests were spontaneously organised by the local residents in 2013	(i) Government decision-making risk (ii) Public opposition risk
18	Kunming Donggang WTE incineration project	2012	Half of the machines became idle because of the shortage of MSW supply. The distance between two WTE incineration plants was too close, resulting in a competitive relationship for MSW resources. Payment of the MSW disposal fees was defaulted from 2012 to 2013	(i) MSW supply risk (ii) Equipment risk (iii) Government decision-making risk (iv) Payment risk
19	Hangzhou Jiufeng WTE incineration project	—	The technical-based, traditional top-down decision-making approach has led to strong opposition from the local community. However, the response from local governments was inadequate and insufficient in dispelling the residents' concerns. On May 10, 2014, more than 5,000 local residents protested against the plant, which eventually turned into a mass incident. Finally, the plant was suspended by the local government to restart the decision-making process	(i) Public opposition risk (ii) Government decision-making risk
20	Wuhan north Hankou WTE incineration project	2010	Due to Hankou's rapid urbanisation, the plant was getting closer to the populated residential and commercial areas. The incinerators were not equipped appropriately. In 2014, the local residents protested against the plant because it has caused serious environmental pollution. In the same year, the project was fined by the local government because of illegal disposal of carbon monoxide and fly ash. Finally, the plant was closed and will be rebuilt on another site	(i) Government decision-making risk (ii) Technological backwardness (iii) Public opposition risk (iv) Environmental pollution risk (v) Defective legal and regulatory system
21	Anhui Huainan WTE incineration project	2014	Both the quantity and quality of MSW supplied did not reach the expected standard, and one incinerator was idle due to a shortage of MSW supplies in 2014. Some required equipment such as waste-transfer stations, garbage trucks, and garbage compression equipment was ill equipped. The transportation cost of MSW was too high to be profitable because of the long distance between the CBD and the plant	(i) MSW supply risk (ii) Lack of supporting infrastructure (iii) Revenue and cost risk

Table 3: Continued.

Number	Project	Operation time	Risk events	Identified risk factors
22	Hubei Xianning Fengquan WTE incineration project	2012	The government did not pay the MSW disposal fees on schedule. The operator lacked experience in investing and operating PPP WTE incineration projects. In 2014, the project was ordered to be suspended for rectification because of toxic gas leakage, substandard sulphur dioxide emissions, and so on.	(i) Payment risk (ii) Insufficient operation capacity (iii) Environmental pollution risk (iv) Defective legal and regulatory system
23	Jilin Siping WTE incineration project	2011	Due to the insufficient MSW supplies, a financial loss has emerged since 2012. In 2015, local residents opposed the plant because of the dust, odours, and noise during production. Finally, the plant was forced to suspend production	(i) MSW supply risk (ii) Public opposition risk (iii) Environmental pollution risk (iv) Revenue and cost risk
24	Tianjin Jixian WTE incineration project	2016	There were residents and farmland within 300 m of the plant. In 2016, thousands of local residents jointly signed a petition protesting against the plant for its negative impact on the environment and health of the local community. In addition, the operator of the plant was found to have falsified its environmental impact assessment and health risk assessment. Finally, the project was required to stop in 2016	(i) Government decision-making risk (ii) Public opposition risk (iii) Defective legal and regulatory system (iv) Environmental pollution risk
25	Lanzhou Fengquan WTE incineration project	2016	The local residents were seriously affected by the leakage of odour caused by poor equipment. Some required equipment such as cleaning vehicles was ill equipped. In 2016, some illegal sewage pipes were found to have been built by the operator of the plant, which led to serious environmental pollution	(i) Environmental pollution risk (ii) Equipment risk (iii) Lack of supporting infrastructure (iv) Defective legal and regulatory system
26	Chongqing Wanzhou WTE incineration project	2014	Due to a serious shortage of garbage from 2014 to 2016, insufficient air could be extracted from the upper end of the trash pit to form the negative pressure needed, which led to a serious odour leakage. A line or two lines were run alternately, accelerating equipment aging. The operator lacks experience in investing and operating PPP WTE incineration projects	(i) MSW supply risk (ii) Equipment risk (iii) Environmental pollution risk (iv) Defective legal and regulatory system
27	Haerbing Shuangqi WTE incineration project	2014	The plant was fined by the local government in 2016 for its excessive emission of pollutants, improper disposal of solidified fly ash, and nonstandard operational management	(i) Defective legal and regulatory system (ii) Environmental pollution risk
28	Hubei Xiantao WTE incineration project	—	The technical-based, traditional top-down decision-making approach has led to strong opposition from local communities. In 2016, the project was cancelled by the local government	(i) Public opposition risk (ii) Government decision-making risk

Table 3: Continued.

Number	Project	Operation time	Risk events	Identified risk factors
29	Nanjing Liuhe WTE incineration project	—	As case 28	(i) Public opposition risk (ii) Government decision-making risk
30	Zhejiang Haiyan WTE incineration project	—	As case 28	(i) Public opposition risk (ii) Government decision-making risk
31	Guangdong zhaoqing WTE incineration project	—	As case 28	(i) Public opposition risk (ii) Government decision-making risk
32	Hangzhou Qiaosi WTE incineration project	2002	Due to Hangzhou's rapid urbanisation, the plant was getting closer to the populated residential and commercial areas. The plant was strongly opposed by the local community for its negative impact on the surrounding environment and health. The plant was officially closed in December 2016	(i) Government decision-making risk (ii) Public opposition risk
33	Feicheng Fengquan WTE incineration project	2011	Due to obsolete equipment, constraints on maintenance funds, and other reasons, the pollution control facilities were running poorly and successive excessive pollution problems occurred. The residents constantly complained. In July 2016, the plant operator was interviewed by the local environmental protection department and required to rectify and reform the situation	(i) Equipment risk (ii) Defective legal and regulatory system (iii) Environmental pollution risk (iv) Public opposition risk
34	Shaoxing zhonghuan WTE incineration project	2008	The project was heavily fined in 2016 because the company falsified and illegally deleted automatic monitoring data of discharged exhaust gases and then deleted historical data to circumvent inspection. The residents complained about the pollution involved but did not receive any responses	(i) Defective legal and regulatory system (ii) Public opposition risk (iii) Environmental pollution risk
35	Hainan Wanning WTE incineration project	—	The technical-based, traditional top-down decision-making approach led to strong opposition from the local community. A mass incident has occurred on 12 January 2017	(i) Government decision-making risk (ii) Public opposition risk

while low-frequency risks mean risk factors rarely occurred (no more than 3 times).

4. Discussion

Similar to previous studies identifying risk factors in the WTE incineration industry, the results in Table 4 indicate that numerous risk factors affect the performance the PPP WTE incineration plants and the development of PPP WTE incineration industry in China. On the one hand, although the conclusions of previous studies are not entirely consistent, they provide sufficient evidence that the performance of PPP WTE incineration projects is heavily affected by critical risk factors such as environmental pollution, government decision-making, public opposition, and MSW supply [4, 23]. On the other hand, emerging factors such as safety and government behaviour risks are unexpectedly identified. The reason may be attributed to the fact that low-frequency risks are easily overlooked, especially when those related to local community health and the environment occurred at the same time [37–39]. Moreover, different studies provide different rankings of the importance of the risks. Some argued that the vital factor affecting the development of PPP WTE incineration projects is not technical problems but deficiencies in government regulations and enforcement [40, 41]. Cheung and Chan [42], for example, concluded that government intervention and public credit are severe risks for PPP WTE incineration projects. In contrast with previous studies,

Table 4: Risk factors frequency statistics.

Category	Risk factors	Frequency
High-frequency risks	Public opposition risk	22
	Environmental pollution risk	20
	Government decision-making risk	18
	Defective legal and regulatory system	15
	MSW supply risk	12
Medium-frequency risks	Equipment risk	8
	Revenue and cost risk	7
	Lack of supporting infrastructure	4
	Policy risk	4
	Payment risk	4
	Technological backwardness	4
Low-frequency risks	Safety risk	3
	Government credit risk	2
	Design deficiency	2
	Contract change risk	2
	Unproven technology	1
	Insufficient operation capacity	1
	Government behaviour risk	1

however, our results indicate public opposition risk to be the highest, followed by traditional critical risk factors such as environmental pollution, government decision-making, the defective legal and regulatory system, and MSW supply risks. These are further analysed in the following.

4.1. Public Opposition Risk. The most important reason for public opposition is the emerging "not in my back yard" (NIMBY) syndrome [14], which sometimes manifests in violent behaviour [43]. WTE facilities can be seen as one kind of LULU (locally unwanted land use), of which the benefits are usually broadly distributed, while most of the costs tend to be localised [44, 45]. WTE facilities face considerable and strong opposition from the local communities in which they are situated because they have potential negative impacts (e.g., smell and dioxin release) on local residents' environments, health, or even property [14, 46]. Protests against incinerators, or anti-incinerator campaigns, have been documented in many countries/regions worldwide [47, 48]. Recently, NIMBYism has become very popular in many potentially hazardous industries in China, especially the WTE industry that, as Table 3 clearly indicates, has led to many WTE projects being cancelled, suspended, or closed before the scheduled closure date. According to public information statistics, at least 10 NIMBY movements related to PPP WTE incineration projects occurred since 2013, for example, the Guangdong Huizhou WTE incineration plant, the Hangzhou Jiufeng WTE incineration plant, and the Nanjing Liuhe WTE incineration plant [49].

Disputes over site selection and decision-making of WTE incineration plants are regarded as the main reason for public opposition [14]. Inadequate disclosure of related information, as well as the inefficient governance and regulation from local governments, are other critical causes by which, once problems occur, it will not only result in a significant loss but also deepen public distrust of the government and PPP WTE incineration projects [49, 50]. Moreover, compensation should also be taken into account [51, 52] for the reason that everyone is highly unlikely to sacrifice their own interests (health and wealth) without adequate compensation [49], with economic compensation considered an effective solution to NIMBY protests [53]. Furthermore, insufficient risk communication between local governments, WTE enterprises, and local communities is also often a significant issue behind public opposition [48, 50].

4.2. Environmental Pollution Risk. Environmental pollution risk occurred in 20 of 35 cases. The collection, delivery, treatment, and incineration of MSW involve complex physical, chemical, and biological processes and can lead to a several forms of environmental pollution [54, 55]. Flue gas from waste incinerators, for instance, contains acid gases, heavy metals, dioxins, and other toxic and hazardous pollutants [23, 24] that cannot be completely eliminated [56]. Waste leachate is another significant source of pollution, and it lacks a mature and reliable treatment technology in China [24]. As happened in Cases 2 and 11, garbage spillage and leakage in MSW collection, delivery, and transportation can also lead to secondary environmental pollution [57]. Consequently, equipment, materials, and technologies for pollution prevention and control need to be used to minimise negative impacts on the environment, which significantly increased WTE operating costs [4, 24]. As one of the most common "negative impacts" of PPP WTE incineration projects, environmental pollution is often caused by the unethical behaviour of practitioners during the construction and operation stage [58], such as through the excessive discharge of contaminating materials and hazardous substance leaks [4], as illustrated in Cases 27 and 33. China's defective legal and regulatory system, which provided the loophole for private sector's illegal activities, may be the main contributing reason [58, 59].

4.3. Government Decision-Making Risk. Government decision-making risk is often manifested as inappropriate site selection

in the field of WTE incineration, which heavily affects the implementation of WTE incineration technologies in the MSW disposal industry [60], as shown in Cases 8, 16, and 24. As one kind of LULU, site selection and government decision-making related to PPP WTE incineration projects involve not only technical issues but also a complex mix of economic, social, and environmental concerns such as perceived risk and public distrust [61, 62]. Thus, an open and consultative decision-making approach with public participation and transparency is seen as an effective way to ensure the reliability and fairness of the government's decision-making approach [48, 61, 62]. However, although cultivating a strong environmental state remains a key part of China's environmental management strategy, the emerging government decision-making risks indicate that the traditional top-down decision-making approach and the command and control regulation are insufficient to deal with the NIMBY syndrome in the WTE industry [47, 63–66]. In addition, it is worth noting that almost all highly protested WTE projects in China are eventually cancelled or indefinitely postponed by the local governments because the local governments will circumvent unrest through increasing opacity or by selecting sites in locations where public opposition is less likely to emerge [64, 65].

4.4. Defective Legal and Regulatory System. Delivering sustainable PPP WTE incineration projects requires a good supportive legal and regulatory environment [26]. However, the legal and regulatory framework for PPPs, especially for PPP WTE incineration projects in China, is still in its infancy [67, 68]. As a new waste disposal approach, incineration technologies have not been widely used in China's MSW disposal industry until recently, despite the first WTE incineration plant in China being built in Shenzhen in 1988. Thus, many relevant laws and regulations that relate to their establishment and improvement are far less than perfect. For example, the price system of power generation with WTE incineration was basically chaotic until 2012, when the National Development and Reform Committee published a regulation entitled *The Notice on Improving the Price Policies of the Municipal Solid Waste Incineration for Power Generation (2012)* in which the conversion coefficient from MSW to grid-connected power was temporarily determined to be 280 kWh/t and the price of grid-connected power is 0.65 CNY/kWh. This led to the excessive use of traditional energy sources such as coal and diesel fuel in many WTE incineration plants to obtain high benefits from electricity generation. Meanwhile, this risk may also rely on existed legislation and regulations being poorly carried out or even not enforced at all [4, 42], resulting in illegal acts such as excessive pollutant discharge and use of outdated technologies, as shown in Cases 7, 14, 16, and so on. In addition, transparency and open decision-making approaches are essential for establishing a good legal and regulatory framework, or WTE operators may violate the technical and safety standards for their own interests [69]. Finally, frequent changes in legislation are also a major cause of legal and regulatory risks, such as laws relating to land use, tax, labour, and environmental protection [70, 71].

4.5. MSW Supply Risk. In contrast with other risks such as public opposition and environmental risk, the MSW supply risk is a specialised WTE incineration project risk. The inadequate quantity and/or quality of MSW supply are two aspects of MSW supply risk [4]. An inadequate MSW supply will affect the efficiency of PPP WTE incineration projects, both economically and technically. On the one hand, the inadequate supply of MSW caused machines to be idle or to be used interchangeably, which can lead to financial loss and reduced revenues because both disposal fees and electricity fees depend on the amount of waste disposal [23]. On the other hand, a serious shortage of MSW supply may cause incomplete MSW incineration, which leads to incineration gas leakage. In terms of quality, MSW with high moisture content and low calorific value cannot be burned directly [59, 72]. If the MSW is of poor quality, the incineration of waste will require auxiliary fuels, such as coal and diesel, which will not only increase operating costs but also lead to equipment damage [23, 73].

Moreover, compared with similar studies by Song et al. [4] and Xu et al. [23] in China, the current study contributes to the identification of PPP WTE incineration project risk factors by a more comprehensive set of cases as shown in Table 5. The comparative analysis between the three studies shown in Table 5 reveals that the identified risk factors changed with improvements in China's political, economical, and social conditions. Consistent with the findings of Song et al. [4] and Xu et al. [23], a variety of economical, social, environmental, and legal risk factors significantly affecting PPP WTE incineration projects in China have also been identified in the current study (including environmental pollution risk, defective legal and policy making, opaque government decision-making, and insufficient and nonlicensed MSW supply) in spite of the rapid growth in WTE incineration implementation during the past decade.

Meanwhile, the rankings of the significance of these identified risk factors are different. In particular, due to rising public environmental awareness and an increasing emphasis on public health along with improvements in the economic conditions and living standards in China [14, 50], public opposition is increasingly becoming a key risk factor affecting the development of the PPP WTE incineration industry. At the same time, the ranking of MSW supply risk has relatively decreased since 2013. This is because the rapid urbanisation in China had resulted in a sharp increase in MSW generation and the central and local governments had issued a series of orientations and regulations to stress the significance of classification in the disposal of harmless and recycled MSW [74–76], by which the quality of MSW is significantly improved [10].

Moreover, some critical risk factors identified in the studies of Song et al. [4] and Xu et al. [23], such as technical risk, payment risk, and government credit risk, have gradually faded out in recent years. The possible reason is that some interim issues, such as government budget deficit and immature incineration technologies, have been gradually resolved with the continuous development of China's social and economic conditions. For example, the percentage of grate furnaces (advanced incineration technologies

Table 5: Comparative analysis of similar studies.

Profile	Song et al. [4]	Xu et al. [23]	The present study
Research methods	Expert interview and site investigation	Literature review and multiple cases studied using content analysis	Literature review and multiple cases studied using content analysis
Number of cases studied	6	14	35
Time range of events	Before 2008	2002–2012	2001–2016, with 80% after 2012
Criteria for case selection	All cases in operation	All cases in operation	About 2/3 of cases in operation
Risk factors identified	10 key risk factors	5 critical risk factors	18 risk factors with 5 high-frequency risk factors
Critical risk factors (high-frequency risk factors) discussed	Government decision-making risk Government credit risk Legal and policy risk Technical risk Contract change risk Environment risk Public opposition risk MSW supply risk	Insufficient waste supply Environmental risk Entry of nonlicensed waste Lack of supporting infrastructure Payment risk	Public opposition risk Environmental pollution risk Government decision-making risk Defective legal and regulatory system MSW supply risk

[10, 77] and widely used in Europe, USA, and Japan) adopted in incinerators in China is about 64%, a figure predicted to increase constantly because of the localisation of the technology and policy support [10].

5. Conclusion

In light of the pivotal role that risk identification, analysis, and response play in the successful development of PPP WTE incineration projects, we conducted a multiple case study to identify the risk factors in China by drawing on the experience and lessons learn from the real-life risk events of 35 PPP WTE incineration plants through content analysis and expert interviews. The results provide a solid foundation for the further risk analysis, allocation, and response of PPP WTE incineration projects. Both researchers and practitioners of the PPP WTE incineration industry in China, including policy makers, WTE professionals, and academic researchers, may benefit from this study by referring to the identified risk factors in policy making, operating performance improvement, critical risk response, and so on. Thus, the present study is expected to shed light on their improvement in performance as well as the development and implementation of WTE incineration technologies in China's MSW disposal industry.

Based on a comprehensive analysis of the 35 selected cases, 18 risk factors affecting PPP WTE incineration projects in China are identified. The findings reveal that the performance of China PPP WTE projects is most affected by public opposition, environmental pollution, government decision-making, the defective legal and regulatory system, and MSW supply risks.

Although the current study contributes to the literature on the management of the PPP WTE industry and PPP infrastructure projects by identifying the risk factors affecting PPP WTE incineration projects in China, it also has some limitations that need to be addressed by further research. First, due to the limitation of case selection, there are undoubtedly other risk factors involved that are expected to be examined by further studies. Second, although multiple case studies were used in the current research, the identification of risk factors for each case was still based on the subjective judgment of experts, and future validation studies are needed using such quantitative or empirical research methods as case-based reasoning technologies and statistical analysis.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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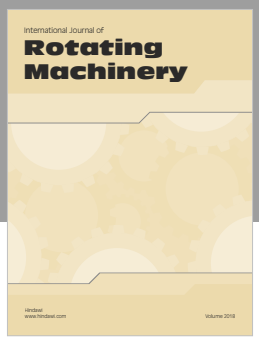

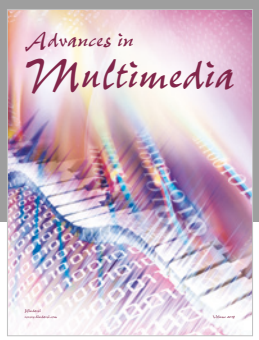

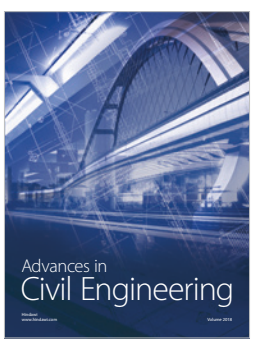

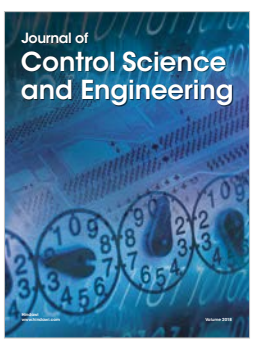

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