INTRODUCTION

The amount of municipal solid waste (MSW) has increased dramatically due to the rapid development of the economy and urbanization during the past decade in China. However, landfill as the dominant MSW treatment method in China occupies a large amount of land resources, contrary to China's sustainable development goals. Waste-to-energy...
(WTE) technology can contribute positively to the power supply, given its advantage of low-carbon content, reduce the consumption of land resources and recover energy. As a result, waste incineration is considered the most effective way to dispose of MSW and plays an important role in China’s sustainable development strategy. As shown in Figure 1, incinerated MSW increased from 3.7 million tons in 2003 to 84.63 million tons in 2017, and the number of incineration plants increased from 47 to 286 during the same period.

In fact, most WTE incineration projects in China are constructed and developed through public-private partnership (PPP) arrangements. PPP is a form of long-term contract-based collaboration between the government sector and private enterprise in which the two parties combine their complementary skills and assume different risk levels to develop infrastructure. This approach can introduce advanced management systems and production experience, as well as a large amount of investment funds from the private sector, to provide more efficient and reduce financial pressures on the government. Due to the benefits of moderate investment scale, large market demand and relatively stable profit, the WTE incineration industry has become one of the most active infrastructure fields and attracts the private sector through PPP arrangements.

However, there are also some obstacles hindering the sustainable development of the PPP WTE incineration industry in China. First, given the complex relationships among stakeholders, long concession periods, and large-scale investment, PPP projects are always associated with many inherent uncertainties and risks, such as government behavior risk, payment risk, contract change risk, etc. Second, WTE incineration plants, which are a type of locally unwanted land use (LULU) facility, face specific risk factors, such as public opposition risk, environmental pollution risk, MSW supply risk, and so on. Third, the risk factors stemming from cultural characteristics, economic development, market situations, and the legal environment vary from one country to another. Thus, many risk factors that are not important in other developed countries often play critical roles in PPP WTE incineration projects in China, such as defective legal and regulatory systems, policy risk, and technological backwardness. Factors from these three aspects can lead to the stagnation or even failure of PPP WTE incineration projects, such as the Beijing Liulitun incineration plant (operational risk) and Jiangsu Wujiang incineration plant (environmental risk). Thus, it is obvious that risk management plays an important role in the success of PPP WTE incineration projects.

Thanks to the joint efforts of numerous scholars worldwide, risk management research concerning PPP WTE incineration projects has gained sustainable achievements, and the emphasis has been on such issues as health problems, public acceptance, decision-making models, economic problems, and so on. However, there are still some deficiencies in the study of the systematic risk identification of these specific projects. First, previous studies identified critical risk factors through case studies, mainly based on practice and past occurrence data rather than potential risk data conforming to risk management knowledge frameworks. The inferences based on past data are difficult to apply, as potential implicit risk factors have not been found in cases involving managers’ significant attention and effective risk management. Investigations based on experts’ experiences, which have been widely used to identify potential implicit risk factors, could effectively remedy this deficiency. Second, most studies have measured the importance of risk factors based only on the occurrence frequency in historical cases without considering the severity degree of those risk factors. In addition, there remain inconsistencies and differences in the research findings of critical risk factor identification.

Therefore, to bridge this research gap, this study aims to identify and analyze the critical risk factors of PPP WTE incineration projects in China by assessing the severity and the occurrence probability of each risk factor based on an empirical questionnaire survey. Compared with similar recent state-of-the-art research, on the one hand, the current study prefers to select events that occurred after 2012, with more cases from different regions of China based on a previous study, as these better represent the current realistic social environment given the geographical scope of the plants and the time.

![Figure 1](https://via.placeholder.com/150)  
**Figure 1**: Number of MSW treatment plants/sites and capabilities of MSW treatment between 2003 and 2017.
range of real-life risk events. On the other hand, potential implicit risk factors which have not occurred in practice will be identified using the empirical questionnaire survey based on case study findings.

This study is organized in six sections. Following this introductory section, Section 2 reports a literature review on the risk identification of PPP WTE projects. Our research method is then used to collect and analyze empirical data in Section 3. This is followed by the results and discussion, including our main findings and a comparative analysis with previous studies. Practical and managerial implications based on our findings are then presented before we draw our main conclusions.

## 2 | LITERATURE REVIEW

A perfect risk identification system is beneficial for practitioners of PPP projects to successfully design and sign contracts, providing risk management along with useful information.\(^1\)\(^9\) Hence, studies of the risk identification of PPP projects have fostered heated debate in past decades. For example, Jin and Dolo\(^2\)\(^0\), Zeng et al\(^2\)\(^1\), Hwang et al\(^2\)\(^2\), and Sarvari et al\(^7\) included detailed risk identification lists in their articles, which to some extent provided valuable references on the construction and operation of different infrastructures applying PPP financing models.

In terms of PPP WTE incineration projects, research conclusions relative to their risk identification and analysis vary among authors because of their distinctive research perspectives and the social environment. In addition to the four studies previously mentioned that carried out a comprehensive and directed risk identification of this field via multiple case studies, numerous other academic scholars offer significant insights. For instance, although the government can transfer risks to private investors, the most serious risks are associated with the government. Kleiss and Imura\(^2\)\(^3\) reported that MSW supply risk (including the quality and quantity of MSW), public opposition risk, and a defective legal and regulatory system should be mainly accepted by the public sector. Cheung and Chan\(^2\)\(^4\) found that the risk factors of PPP WTE incineration projects are significantly different from those of water and transportation projects, and most of the key risk factors are government-related, such as government regulation, government corruption, and government debate risk. In addition, since there have been many public opposition risk events in recent years, this has aroused many researchers' concerns. Achillas et al\(^2\)\(^5\) proposed that public opposition/acceptance risk is the most critical risk faced by this industry. As suggested by Liu et al\(^1\)\(^1\), Wan et al\(^2\)\(^6\), and Ren et al\(^1\)\(^3\), community engagement and the transparency of operations and supervision directly influence the public trust of the government and other authorities, with major impacts on the public acceptance of such projects. In addition, Zhao et al\(^2\)\(^7\) discuss the barriers and challenges of social and technological factors that mainly constrain the development of the WTE incineration industry. Kalyani and Pandey\(^3\) found that poor garbage classification, financial risks, and legal risks were the critical risk factors causing the failure of such projects in India.

Specific to the WTE incineration industry in China, Song et al\(^4\) identified ten key risk factors from six chosen projects in China using interviews, surveys, and visits, and corresponding response strategies for both the public and private sectors were proposed. Xu et al\(^5\) based on content analysis, identified five critical risk factors affecting the performance of PPP WTE incineration projects from 14 selected plants and then provided risk management references by investigating a specific case. Liu et al\(^6\) identified 18 risk factors of 35 PPP WTE incineration plants using content analysis and expert interviews and classified them into three categories: high frequency, medium frequency, and low frequency. Wu et al\(^7\) quantitatively selected 14 critical risk factors from 12 incineration plants and then presented a risk assessment framework by combining two-dimensional linguistic information with a cloud model. Combining experts' judgments (84 experts) and historical data (22 cases), Wang and Zhang\(^8\) adopted a Bayesian analytic approach to forecast risk occurrence probability, and 7 critical risk factors were identified. From a research methodology perspective, of these five publications, only Wu et al\(^7\) ranked the risk factors of PPP WTE incineration projects based on synthetically calculating their probability and severity degree, while most academic scholars have focused only on risk factors' occurrence frequencies in their research.

From the above literature analysis, it is obvious that previous studies have provided important references for the risk identification of PPP projects in various industries. Specific to the WTE incineration industry, first, although many studies have used risk identification and analysis, few have focused on projects in China. Second, conclusions about the level of identified risk factors are discordant and require further study. To represent the latest industry and social status in China, as well as to cover a large range of projects, this study adopts the 18 risk factors identified by the multiple case study in Liu et al\(^6\) and then conducts further risk evaluation and analysis.

## 3 | RESEARCH METHODS

### 3.1 | Overall research framework

According to previous research, the main methods applied in this study are a questionnaire survey based on the experience
and practices of experts on the WTE incineration industry and statistical analysis. The flow of the overall research framework is shown in Figure 2 and includes the following steps:

Step one: Employees from WTE incineration industries, local governments, and research institutions with practical or study experience of such projects are questioned to determine the severity and occurrence probability of each risk factor using questionnaire surveys through the Internet. Valid questionnaires are then obtained by excluding those with obviously arbitrary answers or that were not completely answered.

Step two: Statistical analysis is applied to process and analyze the valid questionnaires. The critical risk factors are identified according to the risk significance index (RSI), which combines the joint function of risk occurrence probability and severity.

Step three: The causes and consequences of the identified critical risk factors are deeply discussed. In addition, the practical and managerial implications are comprehensively analyzed.

### 3.2 Questionnaire design

The questionnaire survey is widely favored by researchers in the study of risk management,24,29,30 as it can effectively collect the opinions of respondents and then provide data for further analysis.

The questionnaire in this research mainly consists of two parts. The first part gathers the sociodemographic characteristics of the respondents, including age, gender, nature of workplace, professional title, and number of years of working or researching in the PPP WTE incineration industry. The aim of this part is to investigate the familiarity of respondents with PPP WTE incineration projects, which is helpful in screening out and analyzing the valid questionnaires. The second part is the main body of the questionnaire, in which the respondents are requested to evaluate the occurrence probability and severity of each risk factor according to a 5-point Likert scale (1 = extremely low to 5 = extremely high). In addition, the meaning of each risk factor is provided before the measurement to ensure that the respondents’ assessments are based on a common understanding of these risk factors.

### 3.3 Samples and data collection

The snowball convenience sampling method was adopted in this study. First, respondents from incineration industries were randomly selected in regions where WTE incineration projects are widely developed in China. Next, respondents from related local governments and research institutions with practical or study experience of PPP WTE incineration projects participated in the current survey. Finally, 200 questionnaires were distributed via the Internet not only to improve their efficiency but also, to some degree, to guarantee their validity.

| Table 1 | Sociodemographic data of the respondents |
|---|---|---|---|
| Profile | Category | Frequency | (%) |
| Age | 18-25 | 4 | 4.76 |
| | 26-35 | 40 | 47.62 |
| | 36-44 | 28 | 33.33 |
| | 45-60 | 11 | 13.10 |
| | 60+ | 1 | 1.19 |
| Gender | Male | 61 | 72.62 |
| | Female | 23 | 27.38 |
| Nature of workplace | Local governments | 7 | 8.33 |
| | Project companies | 42 | 50 |
| | Research institutions | 29 | 34.52 |
| | Other | 6 | 7.14 |
| Professional title | Primary | 6 | 7.14 |
| | Intermediate | 36 | 42.86 |
| | Senior | 34 | 40.48 |
| | Other | 8 | 9.52 |
| Number of years of research/work experience | <2 | 50 | 59.52 |
| | 2-5 | 14 | 16.68 |
| | 6-10 | 10 | 11.90 |
| | 10+ | 10 | 11.90 |
Recovered questionnaires are screened according to two criteria: (a) There are no missing items in the questionnaires, and (b) there is no obvious randomness in the questionnaire, which means that all of the values are the same, or only one or two are different. Lastly, 84 valid questionnaires were recovered with a 42% valid response rate. This is significantly higher than the norm of 20%-30% of most questionnaire surveys in the construction industry, but still commensurate with social surveys of this type, as the response rate of questionnaires is suitable for factor analysis. In addition, the KMO values of Bartlett’s test of sphericity of risk occurrence probability and risk severity are .843 and .898, respectively, both of which are >.8, while the Bartlett’s results of both are <.05, indicating that the scale is suitable for factor analysis.

3.4 Data processing

In this study, mean score (MS) ranking analysis is used to analyze the valid feedback. As the most commonly used method to reflect the central tendency of data, MS has been widely applied in construction management studies to measure and rank the importance of variables. In line with previous studies, ours relies on MS to evaluate the importance of each risk factor. The formula for calculating the MS is as follows:

$$ MS = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + n_1}{N} $$

where $n_i$ indicates the number of people grading a score of $i$ ($i = 1, 2, 3, 4, \text{ and } 5$), and $N$ indicates the number of valid questionnaires.

According to the above formula, the MS of risk occurrence probability and risk severity is calculated. In the next step, the risk significance index (RSI) combining the joint function of risk occurrence probability and risk severity are used to rank the 18 risk factors and then identify the determining critical risk factors. The RSI is calculated using the following formula:

$$ RSI = f(\text{probability}, \text{severity}). $$

4 RESULTS AND DISCUSSION

4.1 Results

The statistical analysis results representing the experts’ professional and empirical judgments of the risk occurrence probability and risk severity are shown in Table 3. The MS of risk occurrence probability and risk severity range from 2.23 to 3.74 and 2.64 to 3.51, respectively, indicating that there is a certain degree of consensus among the respondents, as their marks on these two aspects fluctuate only slightly (1.51 and 0.87, respectively). Among all the risk factors, public opposition risk ranks first in both occurrence probability and severity, with an MS of 3.74 and 3.51, respectively. It should be noted that the safety risk has a higher degree of severity (3.12) but a lower level of occurrence probability (2.57), showing that, although the occurrence probability of security risks is low, once it occurs, it will have a significant impact, which should be closely monitored.

In Table 3, risk impact is calculated using the formula “risk impact = $\sqrt{RSI} = \sqrt{\text{probability} \times \text{severity}}$.” It is clear that the impact of these 18 risk factors fluctuates from 2.481 to 3.623. Thus, the relationship between the risk level and the quantified value of the risk impact can be defined in three groups: high impact (mean $\geq 3$), moderate impact ($2.5 \leq \text{mean} < 3$),
and low impact (mean < 2.5) risk factors, as shown in Figure 3. It is worth noting that the impact values of environmental pollution risk, lack of supporting infrastructure, and government credit risk are all >2.9 and close to 3. In addition to lack of supporting infrastructure (2.99), the risk severity values of the other two risk factors are both >3. As a result, these three risk factors are also regarded as critical risk factors in this study.

In conclusion, six critical risk factors are identified: public opposition risk, government decision-making risk, defective legal and regulatory system, environmental pollution risk, lack of supporting infrastructure, and government credit risk.

4.1.1 | Public opposition risk

As the most important risk factor in this study, the public opposition risk factor has high levels in both occurrence probability and severity. In recent years, anti-incineration campaigns have occurred frequently in China, with a series of negative impacts on the incineration plants such as the cancelation, suspension, and even closing of these projects. The reasons should be analyzed by combining local residents’ psychology, economics, society, etc. First, as infrastructure, the benefits of WTE incineration plants are shared by society as a whole. However, the disadvantages are mainly borne by local residents, causing strong

| Variable                      | Cronbach’s α | KMO  | Bartlett’s test of sphericity | Total variance explained |
|-------------------------------|-------------|------|-------------------------------|--------------------------|
| Risk occurrence probability  | .889        | 0.843| 647.290                      | .000                     | 66.43%                  |
| Risk severity                 | .898        | 0.868| 639.571                      | .000                     | 66.63%                  |

**TABLE 2** Reliability and validity analysis results of the questionnaire

| Risk factor                              | Risk probability | Risk severity | RSI | Risk impact | Risk rank | Criticality |
|------------------------------------------|------------------|---------------|-----|-------------|-----------|-------------|
| Public opposition risk                   | 3.74             | 3.51          | 13.13| 3.623       | 1         | High        |
| Government decision-making risk          | 2.96             | 3.33          | 9.86 | 3.14        | 2         | High        |
| Defective legal and regulatory system    | 3.07             | 3.21          | 9.85 | 3.139       | 3         | High        |
| Environmental pollution risk             | 2.77             | 3.08          | 8.53 | 2.921       | 4         | High        |
| Lack of supporting infrastructure        | 2.85             | 2.99          | 8.52 | 2.919       | 5         | High        |
| Government credit risk                   | 2.7              | 3.13          | 8.45 | 2.907       | 6         | High        |
| Policy risk                              | 2.74             | 3.02          | 8.27 | 2.877       | 7         | Moderate    |
| Government behavior risk                 | 2.69             | 2.99          | 8.04 | 2.836       | 8         | Moderate    |
| Safety risk                              | 2.57             | 3.12          | 8.02 | 2.832       | 9         | Moderate    |
| Payment risk                             | 2.68             | 2.85          | 7.64 | 2.764       | 10        | Moderate    |
| MSW supply                               | 2.62             | 2.88          | 7.55 | 2.747       | 11        | Moderate    |
| Revenue and cost risk                    | 2.71             | 2.76          | 7.48 | 2.735       | 12        | Moderate    |
| Design deficiency                        | 2.49             | 2.99          | 7.45 | 2.729       | 13        | Moderate    |
| Insufficient operation capacity           | 2.55             | 2.9           | 7.4  | 2.719       | 14        | Moderate    |
| Technological backwardness               | 2.49             | 2.7           | 6.72 | 2.593       | 15        | Moderate    |
| Equipment risk                           | 2.39             | 2.69          | 6.43 | 2.536       | 16        | Moderate    |
| Contract change risk                     | 2.42             | 2.64          | 6.29 | 2.508       | 17        | Moderate    |
| Unproven technology                      | 2.23             | 2.76          | 6.15 | 2.481       | 18        | Low         |

**TABLE 3** Overall ranking of risk factors in PPP WTE incineration projects
psychological imbalances, who are against other nearby residents. In addition, public acceptance is also associated with people’s perceptions of the benefits and risks, as well as the trust of the government and relevant authorities. For example, local residents believe that the toxic gases discharged by incineration plants will endanger their health, working and living surroundings, and even property, such as reduced housing prices and failed crop trading. Moreover, the serious imbalance between compensation and loss (health and wealth) can also arouse opposition because no one wants to sacrifice his or her own interests without sufficient economic compensation.

4.1.2 Government decision-making risk

Government decision making is not only related to technical issues but also involves a combination of economic, social, environmental, and governance concerns. This type of risk is usually manifested in unreasonable site selection and project planning, insufficient technical feasibility analysis, and inappropriate investment return rates, which can consequently cause public opposition and distrust, changes in contracts, and suspension or even termination of the project. Causes resulting in decision errors mainly stem from two dimensions: a low level of public engagement and a lack of relevant experience and knowledge. On the one hand, from the perspective of risk management, different opinions and values can be injected and integrated into decision-making systems to enable more socially and morally acceptable decisions and to improve the quality of decisions by public engagement. However, this area has been sparsely examined in China, and it has been increasingly recognized as one of the effective measures enhancing decision-making ability. On the other hand, considering the development of PPP WTE incineration projects in China, the government lacks accurate predictions of demand for such projects or offers unrealistic guarantees owing to limited experience and knowledge of this industry, which can entail substantial future costs.

4.1.3 Defective legal and regulatory system

The success of PPP WTE incineration projects depends on a stable and workable legal and regulatory framework. However, there is no national PPP law in China, let alone laws for this specific field, which leads to different implementation regulations in different locations in China. Thus, it is an inevitable risk faced by the private sector, since it is difficult to determine and adapt to the various rules and regulations in the different locations given China’s vast geographical area. In addition, another factor triggering legal and regulatory risk is that the legal enforceability and execution of relevant laws and regulations are lacking in China, which can provide opportunities for stakeholders to act illegally for their own interests. For example, some projects forge environmental impact assessments and discharge excessive pollutants, causing local opposition and even project suspension, such as the Tianjin Jixian county WTE incineration plant and Lanzhou Fengquan WTE incineration plant. There is also corruption among stakeholders, such as with the Guangdong Huizhou WTE incineration plants. All of these problems significantly affect project operation. In general, much room for improvement remains in China’s current legal and regulatory basis in terms of economic regulations, legislative sanctions, public participation, and consistency between central and local policies.

4.1.4 Environmental pollution risk

Environmental pollution is an inevitable concern with regard to the construction and operation of incineration plants because various types of pollutants are produced during the incineration process, including SO2, NO, H2S, heavy metal ashes, polychlorinated di-benzodioxine, furan, methane, ammonia, hydrochloric acid, hydrogen fluoride, etc, which have negative impacts on people’s health and the surrounding environment. Therefore, local residents are very sensitive to environmental pollution risk when taking into account their own health and living environment. Technology barriers and regulation barriers are two main dilemmas facing the environmental protection of the WTE incineration industry. In terms of technology, the most efficient and environmentally friendly type of technology should be used to reduce pollution. Although the overall technical level is more advanced than ever before thanks to the rapid development of WTE incineration projects in China, some imported equipment and devices are not necessarily compatible with the domestic...
MSW situation and can influence the normal operation of the project.27 From a regulation viewpoint, environmental pollution risk can result from unethical practices.47 For example, some private companies do not comply with discharge regulations and standards, since the government does not conduct proper assessments and because relevant laws and regulations are not in place.

4.1.5 | Lack of supporting infrastructure

This risk factor was not recognized as critical in the multiple case studies conducted by Liu et al.16 but its evaluation in this study is important. This difference in evaluation may occur because some old facilities and aged pipes must be updated to meet current demands, since the volume of MSW disposal has increased dramatically and national and industrial standards have continuously improved.48 These facilities might still be used in the short term, however, they can be a hidden danger in the future and should be closely monitored by project participants. Therefore, lack of supporting infrastructure is identified as one of the critical risk factors by experts, which currently might not frequently occur. Moreover, the effective operation of a WTE incineration plant requires the support of various types of infrastructures provided by the government, such as municipal facilities, roads, water supply and drainage pipeline engineering, gas pipeline engineering, communication, and so forth.9,13 If these are not available in a timely manner or at fair rates due to inadequate preplanning, financial problems, and spatial constraints, the performance of incineration plants will be significantly affected.27

4.1.6 | Government credit risk

As with the lack of supporting infrastructure, the government credit risk factor is also a new critical risk factor identified in this study, despite its low occurrence frequency in Liu et al.16 The nature of the respondents’ work might explain this condition. Since most individuals questioned are from project companies and research institutions and are more sensitive to government credit, they therefore rank it as relatively high in importance. One of the main causes of government credit risk is that Chinese local governments offer many unreasonable and unrealistic guarantees to support and attract the private sector to invest, but then fail to honor their obligations.45 Thus, for private investors, the creditworthiness of local governments is of primary concern when considering whether to carry out a project.42 In addition to this concern, government credit affects the public’s satisfaction with and the potential value of a WTE project.49 If local governments do not fulfill their promises to the public, this will reduce the residents’ support of the incineration plants and even cause public opposition campaigns, which can bring a series of uncontrollable consequences.50

4.2 | Discussion

Many studies have been conducted of the risk identification of PPP WTE incineration projects in China using literature reviews, case studies, questionnaire surveys, etc. Consistent with previous findings,4,9,10,16,28,51 a range of risk factors, such as public opposition risk, environmental risk, and government decision-making risk, in PPP WTE incineration projects has achieved the consensus of previous findings. However, the differences in the identified risk factors lie in the following four aspects.

First, MSW supply risk is not evaluated as a critical risk factor in this study but can be found in the previous research findings and takes second place in importance in Wu et al.’s research. One possible reason is that MSW supply has been ameliorated based on improvements in MSW classification policy in the last few years.51 Based on Liu et al.’s research, among 12 projects with MSW supply risk incidents, 10 projects were conducted prior to 2012, when waste classification policy was almost nonexistent in China. In March 2017, the National Development and Reform Commission and the Ministry of Housing and Urban-Rural Construction issued the “Implementation Plan of Domestic Waste Classification System,” which attached great importance to waste classification and improved MSW supply. Another possible reason is that citizens’ awareness of environmental protection and waste classification has been strengthened, providing better MSW supply to PPP WTE incineration plants.52

Second, payment risk does not show a high degree of either importance or occurrence frequency in the current study, but it appears in the other studies and is ranked fourth in Wu et al.’s research, possibly because of payment risk gradually fading in recent years. In PPP WTE projects, the payment criterion encourages the private sector to participate and provides value to the public sector and government with the achievement of financing innovation.53 Therefore, payment on time and in quantity gradually becomes achievable basic principles of government.54

Finally, lack of supporting infrastructure and government credit risk are evaluated as critical risk factors by quantifying risk importance in the current study, and they are classified as medium-frequency and low-frequency risks, respectively, in Liu et al.’s study. Although supporting infrastructure risk rarely occurs in the 35 cases, it will turn out to be a potential risk for PPP WTE projects due to the rapid increase in WTE incineration plants and the obsolescence of existing facilities,56 which attracted the attention of the respondents. As typical supporting facilities, waste trucks and waste compression equipment are necessary given unprecedented
In the construction and operation practice of the WTE industry, a defective legal and regulatory system comprises a lack of pertinent legal provisions, the insufficient operability and enforcement of laws and regulations, and frequently policy changes.

The central government should gradually propose a pertinent, complete, and operational legal system to standardize the PPP WTE project implementation process. Meanwhile, the local government should also introduce specific regulations and provide a governance framework to avoid illegal behaviors generated by local situations. In addition, governments at various levels should also provide a regulation adjustment and improvement mechanism based on receiving practical feedback from the WTE
industry and on analyzing the difficulty of implementing regulations in order to improve supervision efficiency and reduce illegal activities.

Because regulatory improvement is a long-term and time-consuming process, adequate contract terms are necessary to improve management efficiency under the situation of defective legal and regulatory measures. The respective allocated risk responsibilities of both parties, such as public opposition risk, environmental pollution risk, government decision-making risk, and government credit risk caused by defective legal and regulatory measures, should be specified in the contract. Moreover, standby terms and renegotiation methods for PPP WTE contracts are necessary to help the government or the private sector propose contract adjustments and ensure that their responsibilities are consistent with benefits when the laws and regulations change.

5.4 | Reducing environmental pollution

Environmental pollution risk is generated by improper technology and equipment, the immoral behavior of practitioners, and the incinerable waste supply of WTE incineration plants. Various measures are effective in reducing environmental pollution. First, one must select the appropriate technology and optimize the equipment’s parameters according to the characteristics of local municipal solid waste. In addition, enterprises should regularly inspect equipment to avoid incomplete incineration and excessive emission caused by equipment aging and machine damage. Second, local governments could help enterprises and practitioners comprehensively obey the standards and norms before, during, and after incineration, and severely punish enterprises that discharge and operate illegally in order to reduce immoral behavior. Finally, although citizens are already conscious of garbage classification, stricter and wider implementation of waste classification is necessary to ensure waste quality and to reduce emissions of toxic substances during the incineration process. In addition, stringent pollutant emission standards, equivalent to those in developed countries, such as those in Europe and in the United States, are called upon to reduce environmental pollution.

5.5 | Providing available supporting infrastructure

The successful implementation of PPP WTE projects depends on the available supporting infrastructure, such as waste trucks, waste compression equipment, and waste transfer stations. The government should solve problems such as inadequate preplanning, insufficient funds, sparse site space, and nonconforming existing facilities to provide more available supporting infrastructure. On the one hand, the planning, construction, and operation of the supporting infrastructure should be carried out simultaneously with the main WTE project while adhering to environmental criteria and technical requirements to avoid secondary pollution. On the other hand, the government should fully take into consideration the funds and land space for a supporting infrastructure during the planning phase.

In addition, a relevant supporting infrastructure could be provided by the government or the private sector caused by the default of the government’s replacement. Moreover, drawing lessons from an enterprise’s performance bond required by the government, the private sector could demand that the government establish an open and transparent credit account to ensure government compliance.

5.6 | Enhancing government credit

Government credit could be improved by enhancing the perceived fairness of the public and private sectors and by offering government guarantees.

On the one hand, enhancing the perceived fairness of the public and private sectors is a critical and effective means of enhancing government credit. To enhance the private sector’s fairness perception, the government should strictly perform its legal obligations, assume complete liability for any contract breaches, and stand firm against evading punishment by privilege in cooperation with the private sector. In addition, a public supervision framework and government credit evaluation system with public and media participation should be established in order to avoid the government pursuing its own interests and in so doing harming the interests of the public and enterprises. In addition, it is necessary to establish effective regular communication among the government, the private sector, and the public in order to solve unreasonable and unfair problems, strengthen mutual cooperation, and enhance government trust.

On the other hand, government credit could be achieved by means of contract and performance guarantees. Government punishment for contract breaches should be clearly defined in concession contracts to avoid losses by the private sector caused by the default of the government’s replacement. Moreover, drawing lessons from an enterprise’s performance bond required by the government, the private sector could demand that the government establish an open and transparent credit account to ensure government compliance.
6 | CONCLUSIONS

PPP WTE incineration projects are experiencing a period of rapid development in China. However, various risks have been taken, and the importance of these projects has been changing constantly as social achievements occur. Based on risk factors identified in previous research, a questionnaire survey based on the experience and practices of experts in the WTE incineration industry is used in this study to rank risks based on occurrence probability and severity. Six critical factors are identified, including (a) public opposition, (b) government decision-making risk, (c) a defective legal and regulatory system, (d) environmental pollution, (e) lack of supporting infrastructure, and (f) government credit. After comprehensively analyzing the causes and consequences of these six critical risk factors, practical and managerial implications for these identified risks are presented. The present article identifies the critical risk factors of PPP WTE incineration projects relatively to the current industry reality in China by thoroughly exploring potential implicit factors. The findings are expected to facilitate the effective risk management of PPP WTE projects and to shed light on the sustainable development of the WTE incineration industry in China.

Like much empirical research based on experts’ experience, this study has some intrinsic limitations affecting the generalizability of its research findings. First, the limited sample capacity compared with the entire sample points to the necessity of further research by increasing the sample size. In addition, the intrinsic limitation of the questionnaire survey, which lies in the results being impacted by the research/work experience of respondents, given that even experienced experts are unlikely to encounter all uncertainties and risks, is unavoidable in the current study. Moreover, our analysis of critical risk factor identification shows that risk factors are strongly correlated. Further research on risk relationships and risk allocation should be conducted to manage critical risks more effectively.

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