Critical Risk Factors Affecting the Implementation of PPP Waste-To-Energy Projects in China

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Abstract

Since 2003, Mainland China has been promoting the public–private partnership (PPP) procurement model in the waste-to-energy incineration sector to reduce the waste burying rate and improve environmental quality. Five critical risk factors (CRFs) that affect the construction and operation of waste-to-energy incineration projects have been identified from real-life risk events of 14 PPP waste-to-energy incineration plants through content analysis. These risk factors are *insufficient waste supply*, *disposal of non-licensed waste*, *environmental risk*, *payment risk*, and *lack of supporting infrastructure*. A recently completed PPP waste-to-energy incineration plant, the Shanghai Tianma project, was investigated to learn from the effective management of CRFs. First-hand data about the Shanghai Tianma project was collected, with a focus on project negotiation and concession agreement. Lessons learned about risk management were acquired. This paper presents a detailed study of the contractual structure, risk sharing scheme, risk response measures to CRFs, and project transfer of a PPP project. The study results will provide governments with management implications to prepare equitable concession agreements and benefit private investors by effectively mitigating and managing risks in future PPP waste-to-energy incineration projects.

Keywords: Public-Private Partnership (PPP); Waste-To-Energy Incineration Plant; Risk Management; Project Transfer, China

1. Introduction

The economically developed coastal provinces of China have high population densities. For example, the population density of Shanghai is more than three times that of London and over four times that of Paris. The scarcity of land resources has led to the increasing cost of landfills for waste disposal [1]. The commonly used waste disposal methods are landfills, composts, and incineration, as shown in Table 1 [2] [3]. As one of the most effective ways to change waste into resource, waste incineration reduces wasteland fills and makes them harmless [4]. It is also envisaged to become a major form of waste disposal in China in the future [5]. At present, the domestic waste incineration ratio is around 15% to 20%, whereas the waste incineration rates of Japan, Denmark, and Switzerland have reached 70% to 80% [1]. Generating power from waste incineration is beneficial for conserving resources, improving environmental quality, and realizing the sustainable development of cities [5].

Table1.Waste disposal methods

Methods	Definition	Characteristics
Landfill	The waste collected in specific regions is compacted and filled with soil in a planned manner for natural decomposition.	● Landfills occupy large quantities of land and significantly affect the surrounding environment. ● To reduce transportation costs, landfill sites are usually located near cities, producing environmental pollution. ● The decomposition of waste is slow and normally requires10 to 20 years.
Compost	The biochemical effects of microorganisms are used to decompose and decay	● Compost has high requirements for waste composition and cannot deal with all types of municipal waste.

	organic matter in waste and then convert it into manure.	
Incineration	Waste is burned at a high temperature so that the combustible components are changed into stable gas (flue) after being oxidized and the incombustible components are turned into ash.	● Waste incineration can achieve the harmless reduction and recycling of disposal targets. However, this approach requires the minimum average calorific value of waste to not be less than 3344 kJ/kg. Otherwise, the cost of incineration will increase significantly.

Since the construction of the first waste-to-energy incineration plant in Shenzhen in 1985, waste incineration equipment factories in the country have introduced foreign-developed technologies and equipment suitable for waste disposal in China, significantly reducing the cost of waste-to-energy incineration plants [6]. By the end of 2011, about 120 waste-to-energy incineration plants were operated in Mainland China; these plants have a total processing capacity of 102,000 tons/day and a total installed capacity of more than 2100MW[2]. These plants are mainly distributed in the Yangtze River Delta, the Pearl River Delta, and other economically developed coastal areas. According to the *Twelfth Five-Year Plan for National Economic and Social Development of the People's Republic of China*, which was issued by the State Council, the rate of national urban domestic harmless waste treatment will reach 80% in 2015.

To overcome the fiscal constraints of the government, as well as to make the best use of the advanced production experience and management systems of the private sector, the PPP financing model has been widely used in constructing and developing

waste-to-energy incineration plants, such as the Jilin Siping, Chongqing Tongxing, and Guangxi Laibin waste-to-energy incineration plants [7]. “A public private partnership is a legally-binding contract between government and business for the provision of assets and the delivery of services that allocates responsibilities and business risks among the various partners”[8]. The government or its designated agency awards private entities (including foreign companies) a certain period of franchises through concession contracts that permit the financing, construction, and operation of a specific public infrastructure. The private entity is also allowed to charge users or sell products to settle loans, recover investments, and make profits. When the concession period expires, the infrastructures are transferred to the government for free [9].

Despite the wide use of the PPP financing model for waste-to-energy incineration plants, many uncertain factors affect the implementation of PPP projects during various processes, such as project decision-making, feasibility study, financing, design, construction, operation and maintenance, and transfer, because of characteristics such as large-scale investments, long concession periods, great number of participants, and staggered rights and obligations [10]. This study aims to identify the critical risk factors (CRFs) that affect the construction and operation of PPP waste-to-energy incineration plants and to draw lessons for the effective management of these CRFs through a case study of a recently completed PPP waste-to-energy incineration plant in Shanghai. The lessons learned are expected to provide useful information for constructing and developing future PPP waste-to-energy incineration

plants in China.

2. Research methods

The research methods adopted in this study are literature review, content analysis, and case study. Fig. 1 shows the flow of the overall research framework, which consists of the following steps.

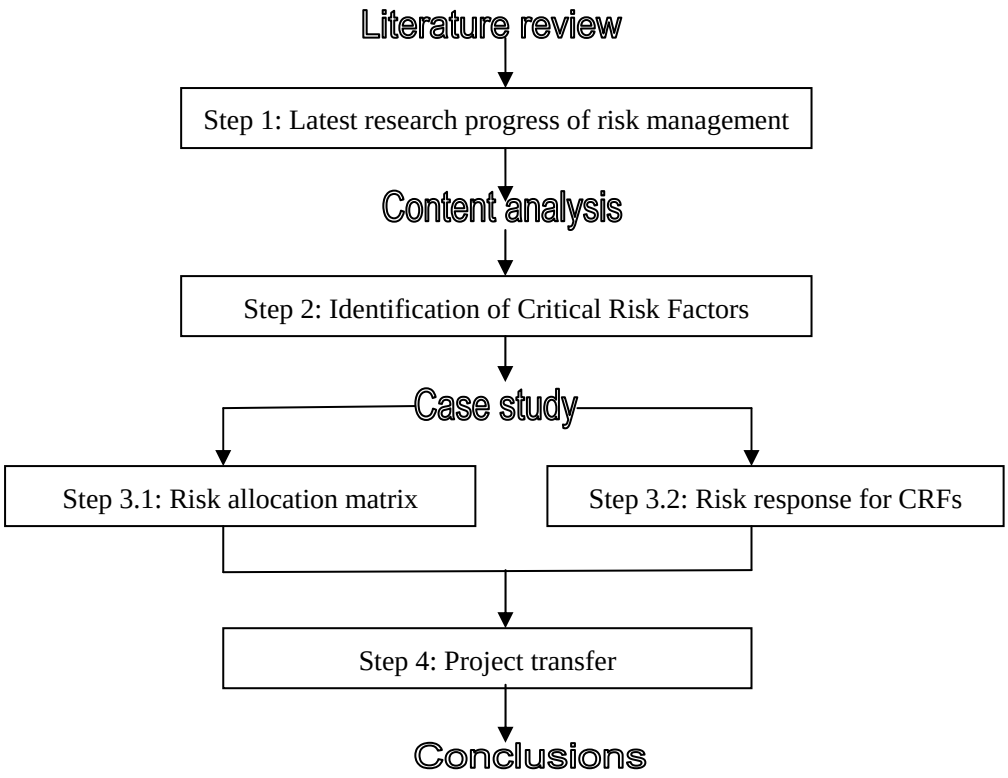

Fig. 1. Flow of the overall research framework

Step one: A comprehensive review on PPP risk management literature published between 2004 and 2013was conducted to understand the latest research progress. The focus of the literature review is to investigate the risk factors for PPP projects in general and waste-to-energy projects in particular.

Step two: Given that few studies have investigated the risk factors of waste-to-energy incineration projects, a content analysis of real-life risk events from 14 PPP waste-to-energy incineration projects in China was conducted to identify the CRFs. These risk events were extracted from journal papers, doctoral/master thesis, and news reports from official media. The systematic analytic process for risk events followed the research flow by [11].

Step three: To understand the allocation scheme of risk factors and response mechanisms for CRFs, a case study of the Tianma waste-to-energy incineration project was presented through a close examination of its concession agreement. Tianma project is one of the latest and biggest PPP waste-to-energy incineration projects in China (constructed in 2013) and has absorbed a great deal of experiences/lessons from the preceding projects. The author has been closely observing Tianma waste-to-energy incineration project since 2012. Data were collected through face-to-face interview, site investigation and engineering document review. According to [12], a case study is regarded as an effective approach for investigating risk management to capture specific project features, gain a detailed understanding of its implementation, and draw useful implications. A case study approach has been widely adopted in studies on PPP projects, including wastewater treatment projects [13], water plants [14], and power stations [15].

Step four: The investigation was also extended to the project transfer after the concession period of the Tianma project. The experiences obtained from the Tianma

project are beneficial for ensuring project viability during the post-concession period.

3. CRFs of waste-to-energy incineration projects

PPP waste-to-energy incineration plants are subjected to a range of risks during the concession period. These risks may arise from multiple sources, such as capital budget, construction time, construction cost, operation cost, politics and policies, market conditions, cooperation credibility, and economic environment [16]. A great number of general PPP risk factors have been identified. Li et al. [17] presented a risk checklist with 46 risk factors for PPP projects. Ke et al. [10] identified 37 risk factors associated with PPP projects in China. Contracts that fail to address risk in a comprehensive manner raise the costs of infrastructure services [18]. Hwang [19] found that most PPP risks are difficult to control and analyze. Therefore, the government and private sector must identify, assess, allocate, and respond to all potential risks properly throughout the whole project life cycle [16].

In the last decade, various studies have looked at the risk management issue in PPP projects. For example, Zou et al. (2008) developed a life-cycle risk management framework for PPP infrastructure projects. Xu et al. (2010) developed a risk assessment model using fuzzy synthetic evaluation approach. Li and Zou (2014) used Fuzzy AHP-Based methodology for PPP project risk assessment. In particular, given the critical importance of appropriate risk allocation in PPP projects, a number of studies have been conducted to explore how to achieve efficient risk allocation. For example, Medda (2007) proposed a game theory approach for risk allocation in

transport PPP project. Xu et al. (2010) developed a fuzzy risk allocation model for PPP projects in China. Jin and Zhang (2011) used artificial neural networks to model optimal risk allocation. All these studies contribute significantly to the body of knowledge and also demonstrate the complexity and obscurity of risks facing PPP projects and the difficulties in managing them effectively.

Typical PPP risks can be classified into systematic risks and specific project risks. Systematic risks mainly arise from external environment. These risks include political risk, social risk, economic risk, and legal risk, which are always beyond the control of private investors. Specific project risks arise from various characteristics of a project [20]. The risk management of PPP projects begins with the identification of risk factors that result from the inherent characteristics of the project itself [21]. Previous studies on PPP projects have covered a wide range of sectors, such as water supply [14], power supply [22], public venue [23], toll road [24], theme park [25], public housing [26], health care and hospitals [27]. However, little attention has been given to PPP waste-to-energy incineration projects. Specific risk factors for the development of waste-to-energy incineration projects, such as strict site selection (environmental risk), waste classification and recycling, and waste transport and waste incineration, are not sufficiently addressed in the literature.

To identify the risk factors specifically for waste-to-energy incineration projects, a content analysis was conducted after the literature review on general PPP risk factors. Information about the risk events of 14 well-known PPP waste-to-energy incineration

generation cases in China was collected for analysis. These projects are located in Laibin, Zhengzhou, Siping, Shenzhen, Wuhan, Ningbo, Chongqing, Zhongshan, Jinjiang, Kunming, Wuhu, and Zhengzhou. They operated between 2003 and 2011, as shown in Table 2. Five CRFs that affect the implementation of projects were identified as follows.

CRF1: Insufficient waste supply. The concessionaires of PPP waste-to-energy incineration plants normally have two ways of obtaining operation revenue. One is the waste disposal fee paid by local governments, and the other is an electricity fee collected by the power grid company. Both fees depend on the amount of waste disposal. Therefore, an inadequate supply of waste will generate electricity and operating earnings that are less than expected, as manifested in cases1, 2, 3, and 4 (Table 2).

CRF2: Environmental risk. Chinese people have not developed the habit of classifying waste. The composition of waste is complex, and it usually contains plastics, used batteries, and electronic equipment accessories. Therefore, harmful gases, dioxins, heavy metals, and other pollutants are generated by waste incineration. These pollutants can seriously affect the health of people around the waste-to-energy incineration plant, as shown in cases 5, 6, 7, and 8.

CRF3: Entry of non-licensed waste. Licensed waste includes waste from the cleaning of houses, offices, streets, squares, parks, and so on. If the waste delivered to incineration plants contain more than the expected moisture content or dust,

construction waste, and other low calorific value of inorganic wastes (see cases 9 and 10), the incineration of waste will require auxiliary fuel (e.g., coal or oil), which may greatly increase the operation cost and even lead to device failure.

CRF4: Lack of supporting infrastructure. Lack of supporting infrastructure exists when the facilities that are necessary for the construction, operation, and management of PPP water projects are unavailable in a timely manner or at a fair price, such as in cases 11 and 12 [10]. Supporting infrastructure is generally not a part of PPP projects. However, it significantly affects the normal construction and operation of PPP projects [28]. For example, the lack of sewage treatment plants that surround waste incineration plants may prevent leachate from being treated in a timely manner and cause environmental pollution.

CRF5: Payment risk. The government may not be able or willing to pay because of social or other reasons [10]. The payment of waste disposal fees and electricity fees require the support and cooperation of the government and the power grid company. However, many uncertain factors may affect the fulfillment of government guarantees and support during the 10- to 30-years period, such as in cases13 and 14.

A close examination of the 14 cases reveals that, although the plants are distributed in different cities with different project sizes and incineration equipment, many of them are subject to common/similar risks (Table 2).

Table 2: PPP waste incineration cases and risk factors

No	Name of project	Operation time	Scale ton / day	Investment amount (100Million RMB)	Concessionaire	Government	Risk events	Risk factors
1	Guangxi Laibin Waste-to-energy incineration Plant	2008	500	2	Laibin China Sciences Conservational Power Limited	Laibin municipal government	Since its operation in September 2008, its daily waste supply has only been 170 tons (the minimum guarantee supply is 450 tons/day as agreed upon in the concession agreement). Waste supply is in serious shortage, resulting in less power generation. As a result, the power plant has experienced losses.	Insufficient waste supply risk
2	Zhengzhou Yingjin Waste-to-energy incineration Plant	2004	1050	2.45	Zhengzhou Yingjin Green Energy Co., Ltd.	Zhengzhou municipal government	Three units can only be operated in turns because of serious shortage of waste. In 2004, the Yingjin Waste Incineration Plant suffered more than RMB10 million in losses. In the first half of 2005, it suffered nearly RMB 11 million in losses.	Insufficient waste supply risk
3	Jilin Siping Waste-to-energy incineration Plant	2011	800	2.7	Siping China Science Energy & Environment Co., Ltd.	Siping municipal government	Given the small urban population of Siping, the daily domestic waste it produces is less than 400 tons. Conversely, the Tiedong and Tiexi Districts have landfill treatment plants, and some waste is placed in the landfill treatment plants. Therefore, the incineration plant experiences a serious shortage of waste.	Insufficient waste supply risk
4	Shenzhen Yantian Waste-to-energy incineration Project	2003	450	2.7	Shenzhen Energy Environmental Protection Co., Ltd.	Shenzhen municipal government	Its designed processing capacity is 450 tons/day, but the waste collection in the Yantian District is only 200 tons/day. Therefore, the waste-to-energy incineration plant experiences a "half-open and half-stop" production condition.	Insufficient waste supply risk

No	Name of project	Operation time	Scale ton / day	Investment amount (100Million RMB)	Concessionaire	Government	Risk events	Risk factors
5	Wuhan North Hankou Waste-to-energy incineration project	2011	1000	5.3	Wuhan Hankou Green Energy Co., Ltd.	Wuhan municipal government	The project is located in a residential and commercial district. Waste incineration produces much harmful gases and toxic dust. The public is strongly opposed to the operation of this project.	Environmental risk
6	Ningbo Fenglin Waste-to-energy incineration Project	2002	1000	4	Ningbo Fenglin Green Energy Development Co., Ltd.	Ningbo municipal government	Accumulated wastewater in the pool cannot be transported to the sewage treatment plant in time. Therefore, the odor affects the surrounding environment. Subsequently, the roads are contaminated, and strong odors are produced at the same time. The domestic waste has high water content and must be stacked for three days before burning.	Environmental risk
7	Shenzhen Pinghu Waste-to-energy incineration Plant	2005	675	2.86	Shenzhen Zhonglian Green Renewable Energy Co., Ltd.	Shenzhen municipal government	The plant area is surrounded by pungent odor and noise. The actual investment of the company greatly differs from the design, and some projects do not meet the design standards.	Environmental risk
8	Shenzhen Nanshan Waste-to-energy incineration Project	2003	800	3.62	Shenzhen Energy Environmental Protection Co., Ltd.	Shenzhen municipal government	Toxic gas caused by waste incineration is directly discharged into the air without treatment.	Environmental risk

No	Name of project	Operation time	Scale ton / day	Investment amount (100Million RMB)	Concessionaire	Government	Risk events	Risk factors
9	Zhongshan Center Zutuan Waste-to-energy incineration Project	2007	900	3.8	Guangdong Chant (Group) Co., Ltd.	Zhongshan municipal government	The waste contains a low calorific value of dust, construction waste, and other inorganic impurities. Therefore, the heat value generated during waste incineration is only four-fifths of the designed criteria.	Entry of Non-licensed waste
10	Fujian Jinjiang Waste-to-energy incineration Plant	2005	750	2.36	Chuangguan Environmental Protection (Jinjiang) Co., Ltd.	Jinjiang municipal government	Waste is not classified. As a result, some building and industrial wastes enter the incinerator and damage the equipment.	Entry of Non-licensed waste
11	Chongqing No. 2 Waste-to-energy incineration Plant	2012	1800	9	Chongqing Sanfeng Covanta Co., Ltd.	Chongqing municipal government	The distance between downtown and the waste treatment plant is large. Waste is not delivered to the waste-to-energy incineration plant in time because of schedule delays in the construction of supporting roads.	Lack of support infrastructures
12	Chongqing Tongxing Waste-to-energy incineration Plant	2005	1200	4.5	Chongqing Tongxing Waste Disposal Co., Ltd.	Chongqing municipal government	The moisture content of waste is higher than expected. No sewage treatment plants treat the leachate.	Lack of support infrastructures
13	Kunming Wuhua Waste-to-energy incineration Plant	2008	1000	3	Kunming Xinxingze Environmental Resources	Kunming municipal government	After the operation of the project, collecting the waste fee was difficult. Moreover, the government and the project company have not agreed on adjusting and collecting the waste disposal fee.	Expanse payment Risk

No	Name of project	Operation time	Scale ton / day	Investment amount (100Million RMB)	Concessionaire	Government	Risk events	Risk factors
					Industry Co., Ltd.			
14	Anhui Wuhu Waste-to-energy incineration Project	2003	600	2.03	Wuhu Lvzhou Energy Co., Ltd.	Wuhu municipal government	The on-grid electricity price of waste incineration is lower than that of thermal power enterprises.	Expanse payment Risk

*The table is summarized from [1], [2], [5], [29] and [30].

*1 USD=6.1230 RMB.

4. Case study of the Tianma waste-to-energy incineration project

4.1 Background of the project

The Tianma Waste Treatment Plant was constructed in 2013. It is located in the Songjiang District with a total area of 400 Mu (591 m in length and 450 min width). Its total waste processing capability is 3,000 tons/day. The plant has two phases. The waste processing capacity is 2,000 tons per day in Phase I and 1,000 tons per day in Phase II. The first phase of the project covers 144 Mu for waste incineration and 193 Mu for ash landfill, and the remaining space is for the incineration area of Phase II. The treatment technology adopted is mechanical reciprocating grate incineration technology. Its total investment is about RMB 1.42 billion (USD 1=RMB 6.1230). The project service covers the Shanghai Songjiang District and Shanghai Qingpu District.

The Shanghai Tianma Renewable Energy Co., Ltd. was awarded the project franchise in 2012 by the Shanghai municipal government for the financing, construction, operation, and maintenance of project facilities in a concession period of 30 years (including the construction period). The waste-to-energy incineration plant will be transferred to the government for free when the concession period expires. The concessionaire, Shanghai Tianma Renewable Energy Co., Ltd., is composed of Shanghai Songjiang Urban Construction Investment Development Co., Ltd., Shanghai Qingpu Investment Co., Ltd., and Shanghai Environmental Investment Co., Ltd. The

Greening and Urban Management Bureau of Songjiang District and the Greening and Urban Management Bureau of Qingpu District are responsible for supplying the required waste to Shanghai Tianma Renewable Energy Co., Ltd. It is also responsible for supervising its operation as well as for the payment of waste disposal fees. The electrical power generated is sold to the Shanghai Electric Power Company, which is guaranteed by the district government. The contractual structure of the Tianma waste-to-energy incineration project is shown in Fig.2.

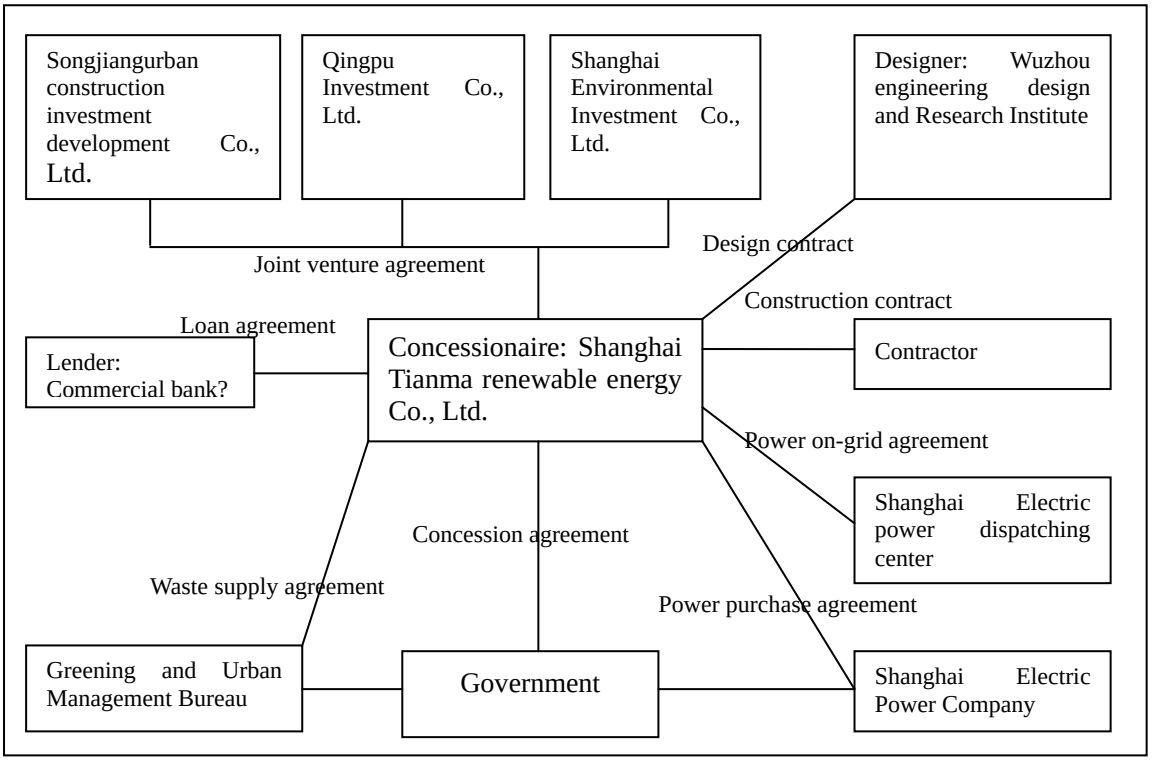

Fig.2. Contractual structure of Tianma waste-to-energy incineration plant

4.2. Risk allocation scheme

The risk allocation scheme in the Tianma waste-to-energy incineration plant, which is summarized in Table 3, was obtained through an analysis of the concession agreement.

The concessionaire is responsible for project financing, construction, operation, and maintenance and it assumes the financing risk, completion risk, and operational cost overrun risk. The concessionaire is required to receive the waste and harmlessly treat it under the concession agreement. The generated exhaust gas and waste residue must meet the relevant national standards under the supervision of the environmental protection department. When the concession period expires, the concessionaire should transfer the project facilities and property to the local government or its designated agency for free (without any compensation). The government is responsible for transporting no less than the guaranteed tons of licensed waste to the waste-to-energy incineration plant during the operation period. The District Finance Bureau monthly allocates waste disposal fees to the Greening and Urban Management Bureau according to the actual waste incineration capacity and disposal fee standard defined in the concession contract. The Greening and Urban Management Bureau pays waste disposal fees to the concessionaire and reserves the right to adjust the waste disposal price based on the comprehensive inflation index.

Table 3：Risk allocation scheme of Tianma waste-to-energy incineration project

No	Risk factors	Risk Allocation		
		Public	Shared	Private
1	Government intervention	×		
2	Nationalization/expropriation	×		
3	Public credit	×		
4	Legislation change	×		
5	Change in tax regulation	×		
6	Land acquisition	×		
7	Delay in project approvals and permits	×		
8	Lack of supporting infrastructure	×		
9	Inflation	×		
10	Public opposition		×	
11	Financing risk			×
12	Completion risk			×
13	Operation cost overrun			×
14	Expense payment risk	×		
14	Change in market demand	×		
16	Price change	×		
17	Waste/labor non-availability	×		
18	Environment risk			×
19	Residual risk			×
20	Force majeure		×	
21	Organization &co-ordination risk			×

The government must not interfere with the construction, operation, and maintenance of the waste-to-energy incineration plant unless doing so is for the protection of public health and public safety or for the fulfillment of its statutory duties. Moreover, the government should attempt to reduce the possibility of a third party interfering with the project. The confiscation, requisition, confiscation, or nationalization of project facilities or any part thereof should be considered as force majeure. However, in case confiscation, requisition, confiscation, or nationalization of the project facility or any part according to municipal regulations is implemented, the risk of loss should be borne by the local government. If the government does not fulfill its obligations

and fails to fulfill such actions within 14 days after urging by the concessionaire in writing, the government will compensate for the losses of the concessionaire due to delays in performance. In case of additional expenditure of the concessionaire due to any change in taxes as well as the implementation, modification, or cancellation of construction standards, environmental standards, and technical specifications of the waste incineration plant, the concessionaire may receive government compensation by adjusting the price of the waste disposal fee. Conversely, if the concessionaire saves expenses or obtains additional revenue, the government has the right to require the concessionaire to turn them over.

The government will assist the concessionaire in obtaining the right for land use, planning permit of construction land and planning permit of construction project to ensure that the concessionaire constructs the project legally. The government is also responsible for the construction of the supporting infrastructure, including municipal roads, water supply and drainage pipeline engineering, electrical engineering, and power access project. The government is obligated to coordinate with the power company in purchasing net output power from the waste-to-energy incineration plant in accordance with national policies.

Even if the concessionaire hires a contractor, including but not limited to construction contractor, construction supervisor, equipment suppliers, and operation maintenance contractors, doing so does not release the concessionaire from any obligation under the concession agreement. The concessionaire assumes full liability for any action or

any omission of its contractors, agents, or direct/indirect employees. The government and the private sector bear force majeure risk jointly. If the project construction or operation period is delayed for over 30 days due to group incidents, the concession period will be extended.

The risk-sharing scheme adopted in tianma projects is generally accordance with the principle of risk allocation, i.e. risk should be allocated to the party who best able to manage it. A comparison between the risk-sharing scheme of tianma project and risk allocation preference reported by Ke et al. [10] is also conducted. The results show that “the government prefers to assume government action related risks, such as government intervention, nationalization/expropriation. Risks which neither the government nor concessionaire may be able to deal with them alone are preferred to be shared by both parties, such as public opposition and force majeure. The concessionaire prefers to take the majority of responsibility for project-level risks, such as completion risk and operation cost overrun” [10].

4.3. Response mechanisms for CRFs

The implementation of PPP projects greatly depends on the effective joint risk response by the government and private investor [31]. This section aims to present the response mechanisms for CRFs adopted in the Tianma project.

CRF 1: Insufficient waste supply risk

Insufficient waste supply causes lower power generation and poorer operating income. To mitigate the insufficient supply risk effectively, the government guarantees to

supply the waste required by the concessionaire in accordance with the concession agreement signed by both sides. The concession agreement of the Tianma project has the following clauses:

(1) The government or commission agents should annually transport no less than the guaranteed tons of licensed waste to the waste treatment plant during the operation period.

(2) If the amount of waste supplied by the government is insufficient to meet the project designed capacity, the concessionaire will provide waste disposal services to a third party upon written consent by the government.

(3) The waste disposal service fee is adjustable. If the waste supply of the government exceeds the guaranteed tons, the waste disposal fee for the exceeded part will be smaller than the guaranteed part (the exact data are not provided for confidentiality purposes). If the waste supply of the government is less than the guaranteed amount, the waste disposal fee will be calculated based on the quantity of the guaranteed minimum waste disposal. The government provides the concessionaire with the guaranteed minimum income.

(4) The Greening and Urban Management Bureau, which represents the local government, should pay the waste disposal service fees on a monthly basis.

In PPP projects, the “take or pay” clause is a common method for guaranteeing operation revenues for the concessionaire. In this project, the concession contract not only sets the minimum quantity of waste supply and waste disposal prices to secure the lowest operating income of the concessionaire, but it also regulates the maximum

supply of waste and waste disposal prices to solve the problem of overloaded equipment operation and to prevent the risk of reducing the service life of the equipment.

CRF 2: Environmental risks

Given that domestic waste in China is not effectively classified, it is characterized by complex waste compositions. Incineration generates harmful pollutants [2]. Therefore, local governments must perform regular and occasional testing on the pollutant emission of waste treatment plants. Items for tests should cover HCL, CO, dust, NOx, SOx, and dioxins. Government reserves the right to check concessionaire's test data. If the test error is less than 5%, the government will accept the test results as correct. Otherwise, it will be solved based on the dispute provisions of the concession agreement. For the substandard items in the terms of emission, the government should, within three days after inspection, issue a rectification notice to the concessionaire on who should perform rectification within three days after the receipt of the notice, which states that the rectification costs shall be borne by the concessionaire. After rectification, the government will organize specialized personnel for re-evaluation and inspection. In case the concessionaire is unable to meet the emissions standards within the rectification period, the concessionaire should bear the losses incurred. However, these provisions only require the government to monitor the emissions of the waste incineration plant. It does not require the government to update the waste-to-energy incineration generation equipment or punish the plant for not complying with the concession agreement. Therefore, the local government may suffer the moral or credit

risk of the concessionaire.

CRF 3: Disposal of non-licensed waste

Non-licensed waste increases operation costs and may even lead to equipment failure. Non-licensed waste specified in the concession agreement of the Tianma project includes the following:

(1) Liquid waste from underground sewers, sludge, or waste soil from urban or individual wastewater treatment plants, filtered waste slag, rubble and gravel, and off-scum;

(2) Bulky waste or wastewater from industrial or commercial areas;

(3) Infectious waste from hospitals or clinics, and human or animal body parts. Waste from slaughterhouses as well as special wastes cannot be treated by urban waste treatment methods because of its flammability, toxicity, or risk of explosion.

(4) The waste cannot be transported by waste vehicles or is unaccepted by waste incineration plants because of its size, weight, or other characteristics, and is excluded from the definition of municipal domestic waste.

The public sector and concessionaire should work together to avoid the transportation of non-licensed waste to the waste incineration plant. Illegal waste should be shipped out of the waste treatment plant for proper disposal. If the concessionaire finds that the government-appointed agent transports non-licensed waste to the waste treatment plant, the concessionaire should report this to the government and submit all available information. At the same time, the concessionaire should immediately command and direct the carrier to transport the non-licensed waste out of the waste treatment plant.

If the non-licensed waste, which is thought to be hazardous, has been dumped near the weighing room or into the storage ditch, the concessionaire has the right to notify the government to remove or require the carrier to remove it out of the waste treatment plant. Moreover, if the non-licensed waste is transported to the waste disposal plant and its source or carrier is unknown, or the carrier fails to move the waste out, the concessionaire should act as a government agent and isolate the non-licensed waste within the project site for packaging, placement, isolation, and preservation. Meanwhile, the concessionaire should inform the government of the storage sites, the general nature of the waste, and its quantity. The government should promptly remove the non-licensed waste or commission others to move the waste out of the waste treatment plant in accordance with relevant laws and regulations. The cost of packing, removing, and clearing the non-licensed waste incurred by the concessionaire should be returned by the government based on payment notes. The concessionaire accepting non-licensed waste does not mean that the concessionaire agrees to amend the specifications or will accept waste that does not meet specifications in the future. If the designated authorities transport non-licensed waste to the waste treatment plant and any harmful substance is emitted into the environment as a result, the government should exempt the concessionaire from any liability and penalties. The government also needs to compensate the concessionaire for all costs and losses that arise from such action.

CRF 4: Payment risk

To minimize payment risk, the concession agreement stipulates the payment process,

payment time, and payment amount for the waste disposal fee. The concessionaire should submit a list of waste disposal service fees to the government within 10 working days at the end of each month and provide all supporting documents for government verification. Within 10 working days after receiving these documents, the government should inform the concessionaire of the reviewed amount so that an official invoice can be issued. The concessionaire is then paid within 10 working days upon receipt of the formal invoice. If the list of waste disposal fees proposed by the concessionaire is disputable, the government will first pay the undisputable part to the concessionaire and then note the disputed issue within 14 days after the list of waste disposal fees is received. The disputed part of the list will be solved through a disputes settlement.

If the unpaid amount is confirmed through the dispute resolution process and the government must pay the concessionaire, the government will pay not only the principal in full but also the interest of such amount from the payable date to the actual payment date in accordance with the current bank loan rate of interest. For the paid amount that involves a later dispute and confirmation that such payment should not have been paid, the concessionaire should return the amount to the government and pay interest for the period from the receiving date to the return date according to the bank loan’s rate of interest.

In response to the change in a variety of costs in construction and operational phases, such as material cost, labor cost, and equipment maintenance and operation cost, the concession contract adds the following adjustment clauses on the waste disposal fee:

the waste disposal fee can be adjusted every two years based on the change in the price index in the past two years. The adjustment is calculated as follows:

$$P_n = P_{n-2} \times (1 + i_{n-1}) \times (1 + i_{n-2}),$$

where P_n is the waste disposal price in the n^{th} year;

P_{n-2} is the waste disposal price in the $(n-2)^{th}$ year;

$i_{n-1}$is the comprehensive inflation index in the $(n-1)^{th}$ year;

$i_{n-2}$is the comprehensive inflation index in the $(n-2)^{th}$ year;

Comprehensive inflation index = [(retail price index ÷ 2 + industrial product price index ÷ 2) -100] / 100.

The National Bureau of Statistics issued the price indexes used in the calculation.

CRF 5: Lack of support infrastructures

The local government should assist the concessionaire in obtaining the legal rights to use the land. During the construction period, the government must coordinate with the relevant departments to facilitate the approval of the project feasibility study, preliminary design approval, and approval of the environmental impact assessment report, among others. The government is responsible for land acquisition, resettlement, and access to water and electricity, as well as site preparation before the commencement date of the project. Moreover, the government also needs to provide supporting facilities, including municipal facilities roads, water supply and drainage pipeline engineering, and gas pipeline engineering. In case the cost of the

concessionaire increases or if the concessionaire fails to produce on time because supporting infrastructure is lacking, the concession period will be extended.

4.4. Project transfer

The management and risk control during the project transfer phase guarantees the sustainable operation of the PPP project. During the 10- to 30-year operation period, waste incineration devices and equipment, and even the plant, will be updated. Clearly, determining the scope of the project transfer is difficult. The quality and serviceability of the plant are also questionable after operating for 10 to 30 years [32]. Therefore, the transfer of PPP projects must address the following questions: (1) How is the scope of the project transfer determined? (2) How can the good condition of the transferred incineration power plant be ensured? To guarantee a smooth project transfer and to address the two questions, the concession agreement of the Tianma project stipulates the following:

(1) Debt clearance. The concessionaire will settle all debts in any kind or nature before the project transfer.

(2) Overhaul of facilities. Within 24 months before the transfer date, the concessionaire will perform a restorative overhaul of the waste-to-energy incineration plant. After the overhaul, the concessionaire will inspect the waste incineration plant along with the government.

(3) Determination of transfer scope. The waste-to-energy incineration plant and all its rights (e.g., ownership, usufruct, etc.) will be transferred to the government or its

designated agency for free. The waste-to-energy incineration plant includes, but is not limited to, the incineration facilities, equipment, parts, devices, equipment, and all alteration facilities. The concessionaire will also transfer the operation manuals, operation records, design drawings, and other information that is reasonably required to the government so that the government or its designated agency can operate the waste-to-energy incineration plant smoothly. The concessionaire also needs to transfer all unexpired contracts with its contractors and suppliers to the government or its designated agency. On the transfer date, the concessionaire will transfer components and parts needed for the government to operate the waste incineration plant normally for 12 months.

(4) Transfer and training of staff designated by the government. Six months before the end of the concession period, the concessionaire will submit a list of the employees employed by the project company, including each employee's qualification, position, and salary. It will also specify which employees can be further employed. The concessionaire will allow the government to interview potential employees at the waste-to-energy incineration plant. After the date of transfer, the government has the autonomy to choose qualified operators and maintenance personnel but has no obligation to employ all or any person employed by the concessionaire. As part of the transfer, the concessionaire will fund the training of the staff needed by the government. Both the government and the concessionaire will develop joint examinations to determine whether the designated personnel are qualified to takeover the operation and maintenance of the waste incineration plant.

(5) Warranty period. The concessionaire will ensure that the waste incineration facilities are in good running condition and are well maintained (except for normal wear and tear). It will also follow the safety and environmental standards of the concession agreement. The concessionaire will further ensure the repair of any defect or damage on the incineration power generation facilities caused by the material, craft, design, or any action or omission of the concessionaire within 12 months after the transfer.

(6) Removal of goods owned by the concessionaire. Within 60 days after the transfer date, the concessionaire will remove all items from the site. The removed items are only limited to the personal items of the employees and items unrelated to the operation and maintenance of waste incineration facilities. If the concessionaire does not remove these items within the above period, then 10 days after the government informs the concessionaire, the concessionaire will be deemed to have abandoned ownership of these items, and the government will have the right to dispose them.

Six months before the transfer date, the government will organize a meeting to negotiate the detailed transfer procedures of the waste incineration project with the concessionaire. The concessionaire must submit a list of buildings, equipment, facilities, and items to be transferred and a list of the representatives responsible for the transfer to the government. The government will also inform the concessionaire of its representatives responsible for receiving the project.

5. Conclusions

In China, a growing number of waste-to-energy incineration projects using the PPP financing model and a variety of risks have been encountered, necessitating the proper management of CRFs to ensure the success of projects. The findings from this study provide a number of practical implications.

First, the analysis of risk events in the 14 PPP waste-to-energy incineration projects reveals that CRFs that affect the implementation of projects principally arise from project operation. These CRFs are insufficient waste supply, disposal of non-licensed waste, environmental risk, payment risk, and lack of support infrastructure.

Second, the proposed risk allocation scheme of the Tianma project provides reference for future PPP projects in terms of allocating risks equitably under the specific political, economic, and social environment of China.

- Political risks or risks directly related to government action should be allocated to the government, such asgovernment intervention, nationalization, public credit, legislation change, change intax regulation, land acquisition, delay in project approvals and permits, lack of supporting infrastructure and inflation.
- Financing risk, completion risk, operation cost overrun, environment risk, residual risk and organization and co-ordination risk are better handled by the private entity.
- Risks that need bilateral joint effort as neither party could manage them successfully without the other party’s commitment and contribution should be

shared by both parties, such as force majeure and public opposition

Third, the risk response mechanisms for each CRF should be cost-effective, realistic, and in line with the significance of the risk. Government guarantees can be properly adopted to mitigate CRFs. For example, the ‘‘take or pay” clause is a common method for guaranteeing operation revenues for the concessionaire. The concession contract should not only sets the minimum quantity of waste supply and waste disposal prices to secure the lowest operating income of the concessionaire, but also regulates the maximum supply of waste and waste disposal prices to solve the problem of overloaded equipment operation and to prevent the risk of reducing the service life of the equipment. Logistical support can be used to help the concessionaire to obtain land use right, planning permit and support infrastructures in a timely manner. Meanwhile the local governments also need to perform the regular and occasional testing on the pollutant emission of waste treatment plants to prevent environmental risk. For minimizing payment risk, the concession agreement need to stipulate the payment process, payment time, and payment amount for the waste disposal fee.

Finally, the principal clauses for the project transfer of the Tianma project are also presented. These clauses are debt clearance, overhaul of facilities, determination of transfer scope, transfer of staff, training of staff, and warranty period. These clauses are believed to facilitate a smooth project transfer process and ensure that the transferred project will be in good running condition.

This research extend the work of previous research by revealing critical risk factors

for waste-to-energy incineration projects in China, where most of project participants are unable to manage them effectively. Furthermore, as risk management in PPP project is challenging around the world, the findings from this study provide global construction community with insight for effective risk management with new evidence from China.

Notably, projects with different characteristics and external environments will suffer from different risks. Although only five CRFs are discussed in this paper, other risk factors cannot be ignored. Further studies are required to examine other risk factors. Moreover, to enhance the general application of results obtained, further validation of research findings through additional cases or empirical studies should be conducted

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