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Bayesian-Based NIMBY Crisis Transformation Path Discovery for Municipal Solid Waste Incineration in China

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Abstract: Environmental conflicts have been a top global focus and issue for human's sustainable development. China is confronted with a serious situation with a rigid demand of ecological governance, in which the "Not In My Back Yard" (NIMBY) crisis outbreaks frequently. NIMBY has a great impact on government management and social stability. This study aims to analyze the NIMBY crisis transformation path for municipal solid waste incineration (MSWI) in China. Considering environmental, social and economic influences, this study seeks to find methods of transforming dangers into opportunities. A conceptual framework for realizing the NIMBY crisis transformation in waste management decision-making was conducted with a hybrid approach. A fishbone diagram was applied to explain the key factors of NIMBY crisis transformation for MSWI. Integrating Bayesian network structure discovery and co-word analysis into a qualitative analysis, searched data and key factors from a literature search engine with specific themes were used for structure learning. The results showed that project location, benefit compensation, publicity and education, public decision, public participation, the rule of law and multiple governance have distinct influences on the NIMBY crisis transformation process in China. In summary, the conceptual framework describes the complex process of NIMBY crisis transformation and helps to deepen data mining for municipal solid waste management (MSWM).

Keywords: Not In My Back Yard; crisis transformation; municipal solid waste incineration; fishbone diagram; Bayesian network

1. Introduction

Currently, one of the critical issues accompanying global economic and social development is the significant increase of the amount of municipal solid waste (MSW) generated [1]. In 2016, the total delivery amount of MSW in urban China reached 203.62 million tons, an increase of 33.83 percent compared to ten years ago [2]. Municipal solid waste incineration (MSWI) can convert most waste into heat and electricity, significantly reducing MSW mass (about 80%) and volume (about 90%), and greatly alleviating the constraint of land resources in densely populated areas [3]. China's 13th Five-Year Plan (2016–2020) clearly states that the capacity of MSWI in the city will account for more than 50% of the total capacity of harmless treatment, of which will be more than 60% in the eastern region by the end of 2020 [4]. Incineration will gradually replace landfill as an important means of municipal solid waste management (MSWM) in the future [5].

However, the local communities where "Not In My Back Yard" (NIMBY) facilities are located, especially in developing countries with high population densities, have made quite strong protests [6].

Increasing environmental awareness of the public, rise in community living standards and rapid development of media have greatly accelerated the outbreak of the NIMBY crisis in China [7]. Annually and with more than five anti-incinerator demonstrations that claimed the relocation of MSWI facilities from 2007 to 2016, which left a dilemma that a facility benefiting public the most was aborted. Among famous public conflicts toward waste incineration facilities, Beijing Liulitun, Guangzhou Panyu, Zhejiang Yuhang and Hubei Xiantao are representative cases. The rising NIMBY protest movements caused by MSW is an immediate and critical issue in the process of urbanization [8,9], which has aroused an interest in how to resolve the NIMBY conflict.

So far, there was a rich academic literature that had examined the drivers [10,11], control measures and relevant resolving experience of the NIMBY crisis [12]. Previous research showed that there were three main causes of NIMBY conflicts. The first source of conflict is the NIMBY facility itself and the process of facility siting [13–15]. Secondly, the resistance is due to the fear that the constructed project might affect the life quality, public health, property value and natural ecosystems in the region [16]. Lastly, NIMBY conflict arises mostly when the local residents have a diverse perception regarding the loss and benefits brought about by the MSWI project [10]. Thus, environmental concern is for self-interest and is one of the causes leading to the NIMBY conflict [17]. Stakeholders have diverse and often conflicting interests. Conflict often rises when stakeholders express different priorities over criteria of decision-making [18].

Suggestions to NIMBY facilitate acceptance mainly includes stakeholder participation [19], transparency of the whole process [20], allowing local residents to benefit economically from new facilitates [21,22], giving public access to decision-making [23], raising public awareness of waste incineration facilities [24,25] and so on. Among them, a growing body of literature put forth that public participation was emerging as a more acceptable option. Public participation could make up the decision makers' knowledge and competence and make them recognize public concerns of public policy [19].

Moreover, much practice and best experience of NIMBY conflict management come from Western countries [17]. Rabe et al. [26] built on provincial experience in gaining public support for hazardous waste facility siting through a voluntary, comprehensive process. Besides, case studies had also explored many specific issues for successful NIMBY conflict resolution. For instance, Drazkiewicz et al. [27] presented findings from original research on four cases of local participatory environmental planning in Germany, and what they suggested can be seen as four different pathways to "success" in participatory planning.

With regards to research methods, the early scholars' researches on the NIMBY problem were mainly qualitative analysis. In the 21st century, scholars' research perspectives on the NIMBY problem are becoming more diversified, and research methods are also changing from qualitative to quantitative. With respect to qualitative research, the methods mainly included a case analysis [27,28], focused interview [17,29]. While in relation to quantitative research, scholars were keen on positivist methodologies that utilized structured interviews [30], questionnaires [31] and other methods to collect data, and then trended with a statistical analysis. Meanwhile, some scholars proposed a combination of qualitative and quantitative methods for the assessment of environmental conflict risk, as evidenced by the study of Liao et al. [32], who put forward a combined method (analytic hierarchy process and fuzzy comprehensive evaluation) and well-presented evaluation results, as a reinforcement of the conventional qualitative and quantitative methods. Surprisingly, rarely considered is the combination of qualitative and quantitative methods as a NIMBY crisis research method.

Data collected through traditional questionnaire, structured interview, etc., are faced with many problems concerning sampling and schedule. Due to the rapid changes of the socio-economic system, the validity and reliability of sampling results and conclusions cannot be ensured. In addition, the insufficient waste service in developing countries makes direct access to relevant and available data from official websites often failed [33]. Nevertheless, co-word analysis not only reduce the data into a structured presentation, but can abstract and project the data from gray literature based on the nature of

words [34]. Bayesian network is one of the most effective theoretical models for uncertain knowledge representation and reasoning applied in numerous fields [35], such as customer behavior [36], energy police [37], supply chain [38], design and manufacturing [39] and environmental governance [40–42]. Importantly, it also has the qualities to be very useful in predicting the effectiveness of various strategies and selecting the best from them [43]. Therefore, the mechanism of Bayesian network uncertain knowledge representation is used to input the relevant uncertain information of the NIMBY crisis, and opportunities and path schemes are mined through probabilistic reasoning.

MSWM is part of the major problems affecting environmental quality and urban sustainable development in China [44]. If the NIMBY crisis in MSWI is resolved appropriately, it will be favorable to improve the legal system, raise the government management level and enhance citizens' involvement. There is an essential difference between a modern crisis and traditional crisis. People have been unable to solve a modern crisis through past experience and paradigm [45]. As a result, exploring how to realize the NIMBY crisis transformation caused by MSWI is a research area that has not been fully developed in the literature [32]. It is well known that crisis is composed of danger and opportunity. This paper holds that crisis transformation requires that digging and grasping opportunities from dangers is the basic principle for crisis response. It emphasizes transforming the dangers into opportunities, not merely eliminating the danger. Besides, this study uses data mining and structure analysis to demonstrate the factors related to the NIMBY crisis transformation for MSWI. Also, as the basis for the research, a conceptual framework is built on a fishbone diagram. Findings indicate that project location, benefit compensation, publicity and education, public decision, public participation, the rule of law and multiple governance are the main factors in realizing the NIMBY crisis transformation for MSWI in China. The implications of this study could be taken into consideration during the development and evaluation of policies related to MSWI, as well as when considering how to promote the smooth operation of MSWI plants.

2. Materials and Methods

The study seeks to propose a conceptual framework for transforming the NIMBY crisis, which allows for government to make sound decisions. This requires the exploration of key factors around MSWI NIMBY issues and involves getting relevant data. Additionally, another important aspect relating to the content of a conceptual framework is path discovery. Utilizing multiple methods, there were three main stages in the study: (1) Applying a co-word analysis to obtain key factors and relevant data upon which to base processing data, (2) structure discovery by Bayesian network to discover the path, and (3) design and development of an analytical framework by a fishbone analysis approach to analyze results, and assist the government or enterprises to resolve the NIMBY crisis. Figure 1 presents an overview of the NIMBY crisis transformation for MSWI.

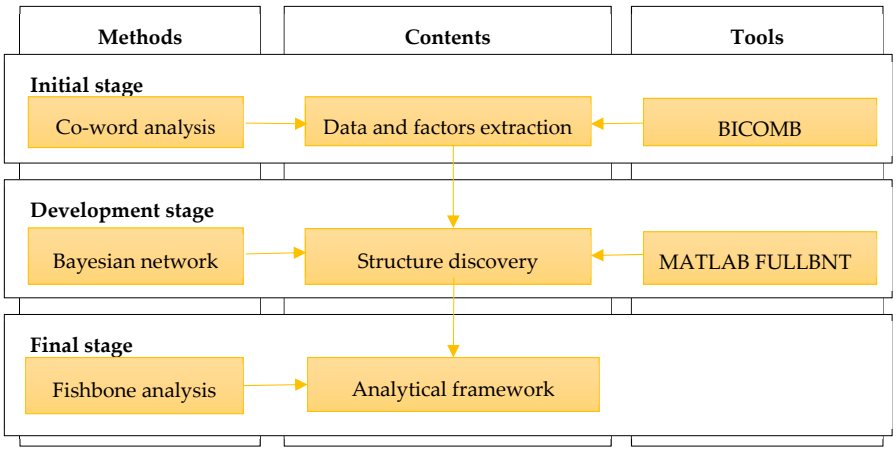

Figure 1. Overview of the 'Not In My Back Yard' (NIMBY) crisis transformation for municipal solid waste incineration (MSWI).

2.1. Co-Word Analysis Approach

The co-word analysis approach for bibliometric has been widely used to a variety of fields since Callon et al. proposed it [46]. Some of these fields include solid waste [47], risk assessment [48], consumer behavior [49], internet of things [50], etc. Co-word analysis finds relationships between topics by calculating keywords that appear together in the same article [51]. According to data frequency of text, links and nodes of network, centrality and interactivity of the network, as well as transformation of the network, the co-word analysis approach structures the data into different levels of research [34]. What is more, network analysis of literature metrology can quantify the structure between indicators, which has become a hot topic in recent years [52].

Reliable literatures from the mainstream search engines can provide the detailed information and process the latest statistics [34]. China National Knowledge Infrastructure (CNKI) is one of the most updated, comprehensive, powerful and widely used search engines in China. China's NIMBY crisis is a specific Chinese issue, and the collected data should take into account the local situation. Through searching on the CNKI website by using the words "MSWI" or "MSW plant" and "NIMBY" or "NIMBY conflict" or "NIMBY crisis", the statistical data from 2008 to 2018 were collected conveniently and objectively. In order to ensure the accuracy of the data, it was necessary to exclude abstracts, news, meeting abstracts, book reviews, editorials and articles that do not match the search subject by artificial interpretation.

Firstly, the use of BICOMB software allowed for the discovery of the initial word-context matrix. The rows and columns of the word-context matrix were keywords and context respectively. If a keyword appeared in the context, it was marked as 1, indicating that there was a connection arc between the keyword and the context. Based on the core topics, the keywords that represent the traits, causes and strategies of MSWI NIMBY conflicts were selected. Secondly, words holding lower frequency, expressing ambiguous or performing insignificantly were ignored such as "government governance", "NIMBY government" and "conflict government". Then, the different variant forms of synonym words such as "benefit compensation" and "compensation mechanism" were eliminated and combined. Finally, a word-context matrix of 14 rows and 58 columns was gathered, as shown in Table A1. Put differently, 14 words with a frequency of more than two were extracted for the following analysis.

2.1.1. Influencing Factors and Goals of NIMBY Crisis Transformation for MSWI

The waste incineration plant siting process involving different environmental, social and political criteria is a complex process, which includes all factors of the principles of sustainable development [53]. It is likewise a complicated process for the NIMBY crisis transformation for MSWI. The words in the word-context matrix were divided into the main factors and goals of the NIMBY crisis transformation, trying to avoid repetition of intrinsic association between each other and to consider the overall aspects. The specific situation was as follows, and the meaning of all acronyms are listed in Table A2:

- Project Location (PL): It does not simply refer to the behavior of "site selection", but rather the characteristics of the MSWI project itself and the factors to be considered in site selection. Negative externalities of the NIMBY facility [13] are concentrated on relatively few individuals living in close proximity whereas the benefits are dispersed across the wider population [14]. Consequently, it inevitably triggers resistance from those who believe their benefits are damaged, and the intensity of resistance is closely related to the intensity of the negative external effect of NIMBY facilities [15]. Moreover, technology is the key criterion for facility siting, in particular for the energy facilities [54]. To this end, increasing investments is imperative for improving incinerator quality and safety.
- Public Risk Perception (PRP): It is a perceptual factor that generally is dependent on the various perceived risks and the public own social experience. This is based on the judgment of cultural

and value factors [55]. Public perceived risks of NIMBY facilities mainly concentrate on four aspects: Safety and health risks [56], environmental risks, benefits risks and reputation risks [57].

- Public Attitude (PA): It refers to the public's acceptance of MSWI facilities, which plays a major role in influencing the effectiveness of any MSWM plan and its smooth operation [1]. It is affected by many factors, such as a demographic variable [58], public risk perception [59], the distance away from one's home or community [60], location decision-making process of NIMBY facilities [61,62], information asymmetry [63], etc.
- NIMBY Conflict (NC): It is a social movement caused by the refusal of residents to NIMBY facilities. It occurs when conflicts between human activities and geographic circumstances are generated in different regions, ways and forms in a shifting society [37].
- Benefit Compensation (BC): It mainly consists of direct compensation and indirect compensation [64]. Direct compensation includes but is not limited to construction of public facilities, allocation of gratuitous fund, assistance of low-income residents and provision of employment opportunities. Indirect compensation is provided by setting up a fund to returning to residents and establishing a system of mandatory environmental pollution insurance for NIMBY facilities. There is a clear relation between the intensity of local conflict and the role of compensation [10]. However, economic compensation is only suitable for low-risk NIMBY facilities. With any sense of civic duty to host infrastructure exhausted when compensation is offered to nuclear facilities [65].
- Public Participation (PP): It focuses on the role of the public in government management. And it is a means to empower formerly marginalized individuals [66]. The level of involvement determines the likelihood of the public to get engaged in such activities as NIMBY [16]. Scholars who study the NIMBY problem have already recognized the value of public participation. In fact, an increasing number of planners are also replacing the "market led" approach with the "community governance" approach, so that local community residents can participate in the entire process [23].
- Public Decision (PD): It emphasizes that the public has the discourse right on project decisions, directly affecting quality of policies, acceptability of policy plans and efficiency of policy implementation. Public decision is the key to resolving NIMBY conflicts, and all stakeholders should make decisions with equality [23].
- Information Publicity (IP): It is defined as the timely transmission to the public of the project construction plan, key content of the environment impact assessment statement report, specific information of the operation and management, project operation safety and treatment plan of the pollution problem, etc. There are different types of transmission channels, including the government's official website, hearings and other reliable information exchange platforms [7]. Government or enterprises should disclose relevant information in the decision-making process of NIMBY facilities, which can eliminate public concerns [20].
- Publicity and Education (PE): This relates to the use of popular science propagandizing column, community colleges, special propaganda and other ways to enhance the scientific literacy of the general public [67]. Publicity and education can change people's basic environmental concept and raise their awareness of environmental protection, thereby reducing the probability of NIMBY conflicts [24,25].
- Multiple Governance (MG): This relies on a decentralization system that allows enterprises and the public to be part of public governance, which can promote the effective solution of social problems. Cooperation of multiple subjects can make public policies effective, fair and sustainable. Since the public has already gone beyond the limitations of the early rational choice theory, with more powerful motives to solve social dilemmas [68].
- Negotiation (NG): It stresses on the use of a variety of communication methods to maximize the scope of communication so as to enhance the effectiveness of the negotiation. It plays an important role in the ultimate transformation of the NIMBY crisis [67]. During the negotiation process, the public can understand the risk assessment and project decision-making, which can

help to increase the transparency of the risk assessment process and improve the technological level of the project. It can also modify the public's erroneous perception of risk and ultimately increase the public's acceptance [69].

- Rule of Law (RL): It includes special provisions for the location and operation of MSWI facilities in relevant legislation [70]. The legal system is the guarantee of public participation, which helps to enhance people's trust in the government or enterprises [71].

In the early phase, environmental conflicts were the environmental problems of individual group events. While under the complex social background, various factors evolved into multi-factor environmental group events. Therefore, environmental conflicts must be placed in the realistic social stability system [30]. As a major innovation in social governance, risk assessment of social stability in China serves as an institutionalized effort in the context both of social transition and social stability era. So, this paper regards the reduction of the social stability risk (SSR) as an important ultimate goal of the NIMBY crisis transformation for MSWI.

In environmental planning, decisions about infrastructure land are increasingly causing conflicts, and risk management has become crucial, particularly with regard to contested waste plants [72]. Hence, improving the risk management (RM) ability is an additional goal of the NIMBY crisis transformation for MSWI.

2.1.2. Data Processing

In the word-context matrix, the number of elements with a value of 0 is far more than the number of non-zero elements, and the distribution of non-zero elements is irregular. As such, the word-context matrix is a typical sparse matrix, which cannot be directly used to analyze the NIMBY crisis transformation path for MSWI. If dimensionality of the matrix is reduced before calculating semantic similarities, the results can be improved [73]. An appropriate mathematical way to achieve this is using singular value decomposition (SVD) [73]. The SVD is utilized to obtain the singular value and singular vector of the word-context matrix. Then the distance matrix between the word and the context is calculated according to the Euclidean distance formula. Depending on the above method, the direct semantic relation between the word and the context is established. Compared with the initial word-context matrix, the semantic distance calculated by the SVD of the word-context matrix has a higher distinction, which further narrows the distance between closely related context and word [74]. Finally the data in the distance matrix of words and context is normalized.

2.2. Bayesian Network Structure Discovery

Bayesian approach is an attempt of dynamic modeling on the NIMBY crisis transformation. Admittedly, other posteriori conceptual models, such as review technique and graphic evaluation and event tree analysis could have advantages in the field of project and technique, but not in the field of policy implementation, which is a field with high uncertainty, especially with human behavior [41]. Bayesian network is a mature graphical representation method that uses Bayes' theorem to encode conditional probabilistic relationships among uncertain, unpredicted, imprecise and complex variables [75]. It is a powerful tool, which can integrate both quantitative and qualitative data and can be used for the fusion of information coming from dissimilar sources having varying degrees of reliability [76]. In addition, Bayes' theorem can also perform rule learning and statistical inference, mining potential relationships between data and achieving multiple tasks, such as classification, prediction and causal analysis [77]. For the NIMBY crisis, the structured and non-structured information coexist, and the information is relatively uncertain. Therefore, the Bayesian structure is conducive to finding opportunities and path schemes, and then reducing NIMBY conflict.

A Bayesian application with search data was constructed. The method could overcome the deficiencies of qualitative method by means of objective data, structural analysis and complex Bayesian calculation [41]. Structural learning and parametric learning are the core components of Bayesian network construction. Structural learning algorithms can be divided into constraint-based learning,

algebraic and geometric based learning and scoring and searching-type learning approaches [78]. Scoring and searching-type learning approaches include algorithms such as K2 [79]. The problem of learning the structure of a Bayesian network from a previously given set of observational data has been studied [80]. So structural exploration was applicable to the uncertain relationship between the factors involved in NIMBY crisis transformation for MSWI.

FULLBNT toolbox is an extremely powerful Bayesian network toolbox (MATLAB environment) to support a variety of parameter learning and structure learning algorithm [81]. Bayesian construction of the analyzer through nodes assignment and their relations is created in MATLAB using the FULLBNT toolbox. The application process of the Bayesian network can be summarized in five main steps:

- Step 1: Data discretization. Each node must contain a set of discrete values (continuous values need to be discretized). This paper used three levels (low, medium, high) nodes. So the segmentation was set as [0.2, 0.8, 1]. Trichotomy is a prevalent and simple but effective segmentation approach [41]. In fact, more than three segmentations may not bring any improvement on simulation effect but increases the amount of calculation [41].
- Step 2: Node selection. Bayesian network does not highlight the independence of all factors, but only requires that those factors are not highly correlated in the study area [82]. Park and Kim [83] even argued that dependence existed among factors, and you obtained a wrong result unless you took care of the interdependency of the factors. So the 14 keywords obtained by the co-word analysis could be directly used as the nodes of Bayesian network without strict consideration of their independence.
- Step 3: Hierarchy and structure. The reference to expert knowledge is helpful to determine the Bayesian network structure. Here, it is generally accepted that putting forward some priori paths as hypotheses in literature [84]. For example, project location, public risk perception and public attitude have an impact on NIMBY conflicts [59,60]. So, PL, PRP, PA and NC could be located in a relatively high hierarchy. RL, PE, IP, NG, BC, PD, PP and MG can be set in the middle hierarchy as a measure to resolve the NIMBY crisis for MSWI. SSR and RM are goals in NIMBY crisis transformation and can be set in the low region from up to down.
- Step 4: Parameter learning. Parametric learning adopts a maximum likelihood estimation algorithm. Data is needed to perform parameter learning on the Bayesian structure. Data can be generated using forward standardized data after discretization. The learnt parameters can be visualized.
- Step 5: Dynamic evolution. Dependence and independence relations can be represented compactly in a class of graphs known as acyclic, directed graphs. The nodes are connected by arcs, indicating potential dependencies between variables [85]. And the direction of the arc from the so-called parent to the child, signifies the direction of influence [85]. Probabilistic networks can be seen as compact representations of "fuzzy" cause–effect rules that, contrary to ordinary (logical) rule-based systems, is capable of performing deductive and abductive reasoning as well as causal reasoning [86].

The above settings are uncertain, and the structure requires a data training process. A structure model with a probability analysis can adapt to the changes, and explain quickly the new appearance.

2.3. *Analysis Framework of NIMBY Crisis Transformation*

As long as NIMBY conflicts are formed, they will undergo a series of dichotomous transformations [87]. Likewise, the NIMBY crisis has the same dichotomy, showing two aspects of "danger" and "opportunity". Namely, crisis is composed of danger and opportunity. Dangers suggest negative impact of the NIMBY crisis on politics, economy, environment and society. These dangers include risk of decrease in public trust in the government, risk of decline in public confidence in regulatory practices, risk of economic losses, risk of environmental contamination and social stability risk, whereas opportunities indicate positive "social productivity" that is hidden in the NIMBY crisis.

It can dig potential opportunities from dangers, such as enhancing public trust in the government, rebuilding public confidence and improving economic, environmental and social benefits. While alleviating or even eliminating danger, seizing the key opportunity is a must. It is conducive to force environmental protection departments to innovate, nurture more environmental protection organizations and promote citizens to attach importance to the environment. Finally, the NIMBY crisis is successfully transformed from dangers to opportunities.

From the perspective of politics, the NIMBY problem is rooted in the decrease of people's trust in the government, decline of people's confidence in regulatory practices and information asymmetry [88]. Therefore, three factors (trust, confidence and information) are essential to realizing the NIMBY crisis transformation for MSWI, which form a stable triangle and are indispensable.

The fishbone analysis method is also named as the cause analysis and branches figure analysis. Kaoru Ishikawa, a Japanese management master, invented it to find out the root cause of problems [89]. It is structured and systematics in nature [90], appropriate for qualitative analysis. Recently, a fishbone analysis has been applied to public management field by scholars. Luo et al. [91] established a fishbone diagram model to analyze the causes of all spherical tank leakage events, and then they proposed specific measures for reason accidents, which have greater occurrence probability to eliminate or reduce the risk of consequences.

With the aim of providing an in-depth understanding of the NIMBY crisis transformation and a base for subsequent analysis, the study adopts an analytical framework combining a fishbone diagram and structure discovery, presented in Figure 2. The whole fish consists of tail, skeleton, branches and head. And the head and tail both are triangles of three elements. The tail is seen as the NIMBY conflict, and PL, PA and PRP are considered as the main causative factors of the NIMBY conflict. The head is made of the information, trust and confidence, including two goals (MR and SSR). Then the determined leading causes' items (PE, NG, PD, MG, RL, IP, BC, PP) of the NIMBY crisis transformation, which are represented by big branches. The skeleton connects the head to the tail, meaning the transformation from danger to opportunity. Based on the principle of triangle stability, in order to realize the NIMBY crisis transformation of MSWI, it is necessary to take action to eliminate dangers (destroy the triangle on the left) and seize opportunities (form the triangle on the right).

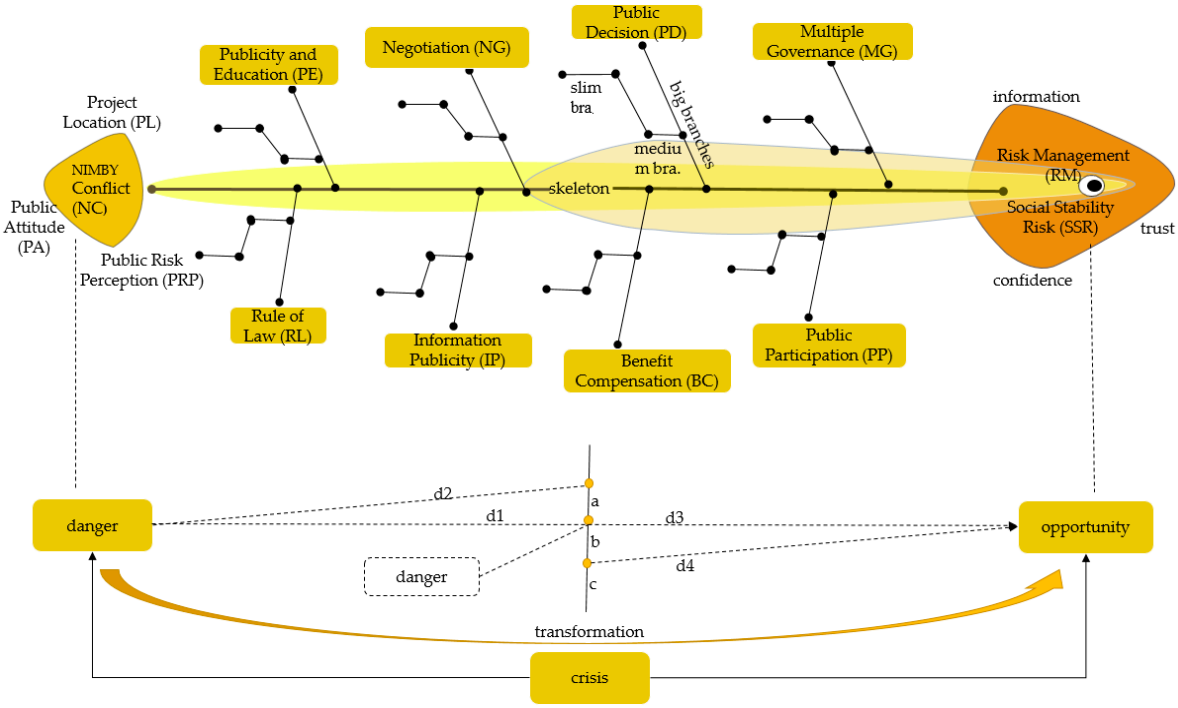

Figure 2. The fishbone diagram of NIMBY crisis transformation for MSWI.

The node in the path from danger to opportunity is represented by the branches. As shown in Figure 2, there are many paths from danger to opportunity. You can take "paths with fewer nodes" (d1→b→d3) or "multi-node paths" (d2→ab→d3, d1→bc→d4 and d1→abc→d4). Crisis transformation can be achieved by distinct paths, but there are differences in efficiency and stability.

The number of nodes in the path reveals the length of the path. The longer the path is, the less efficiency the policy is. However, usually, the more nodes there are, the more measures the government can take and the more stable the policy is. In addition, each transformation needs consumption to reduce danger and capture opportunity. There may be a worse situation where the danger is constantly changing along with the development phases of the facilities (such as hidden danger marked by the dotted box). As a consequence, long paths with many nodes are prone to new risks in the halfway. d1→b→d3 has only one node, indicating that the path is efficient but unstable. d2→abc→d4 (three nodes) may be the most stable to a certain degree, but lacking of efficiency. d2→ab→d3 and d1→bc→d4 share the same node number, so the more stable path should be chosen. Efficiency and stability are optimal simultaneously, which is an ideal transformation path. Nevertheless, in reality, there is generally a contradiction in efficiency and stability. The paths discovered from the study always involve trade-offs between the two dimensions.

3. Results

One of the most effective methods for learning Bayesian network structure is the K2 algorithm [92]. The K2 algorithm is a greedy search algorithm that works as follows. Initially each node has no parents, after which in every step it adds incrementally that parent whose addition most increases the score of the resulting structure. When the addition of a single parent cannot increase the score, it stops adding parents to the node [93]. Since a fixed ordering is used, we do not need to check for cycles, and can choose the parents for each node independently [93]. The K2 algorithm receives as an input an ordering of the variables, which can have a big influence on its result [92]. The reference to expert knowledge and hypotheses in literature is perceived as a node ordering inference method. With the MATLAB and FULLBNT toolbox employed, this study gets two valid results, shown in Tables 1 and 2 and Figures 3 and 4, from the above data and analysis. These two results correspond to one input ordering respectively. Figures 3 and 4 are visualized through the biograph viewer, while Tables 1 and 2 can be exported from the mat file named score in the MATLAB workspace window. The K2 algorithm creates Bayesian networks that extract pronounced features from the data and attempt to minimize bias from overfitting or sampling error [94].

Table 1. Bayesian scores for each factor of simulation I.

Factor	Score	Factor	Score	Factor	Score	Factor	Score	Factor	Score
PL	25.43	PRP	3.61	PA	20.90	NC	26.80	RL	28.71
PD	22.55	NG	20.04	PE	37.09	PP	37.58	IP	10.07
MG	20.06	BC	28.23	SSR	36.29	RM	18.44		

Table 2. Bayesian scores for each factor of simulation II.

Factor	Score	Factor	Score	Factor	Score	Factor	Score	Factor	Score
PL	25.43	PRP	3.61	PA	20.90	NC	26.80	RL	25.67
PD	22.55	NG	32.26	PE	37.09	PP	38.97	IP	10.07
MG	20.06	BC	18.92	SSR	36.29	RM	18.44		

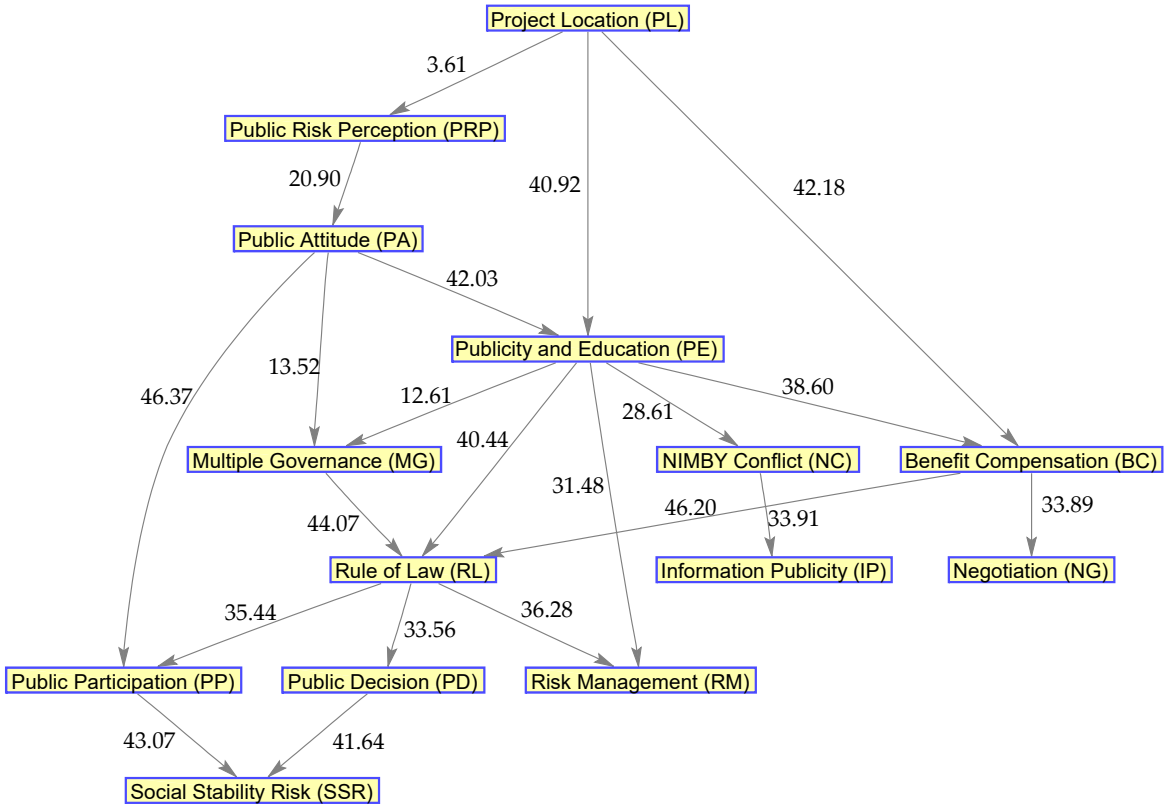

Figure 3. Bayesian simulation I.

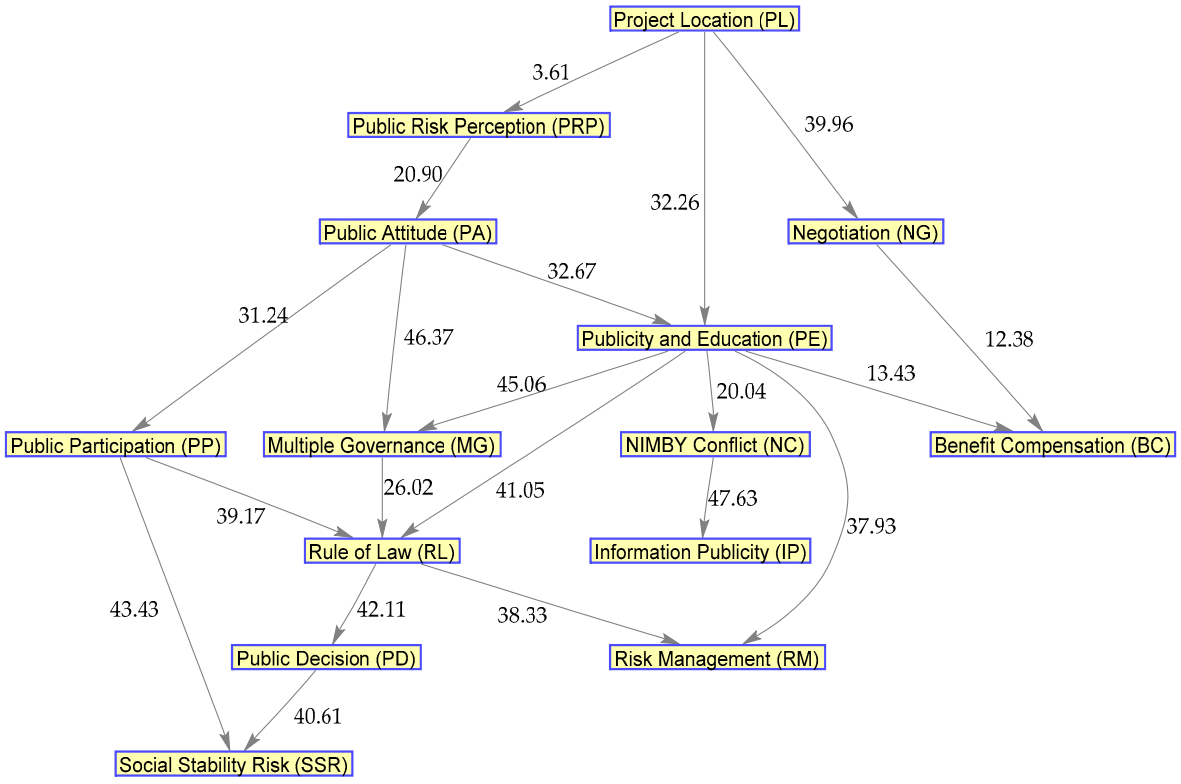

Figure 4. Bayesian simulation II.

A Scoring criterion for the Bayesian network is a function that assigns a value to each directed acyclic graph under consideration based on data. Currently, the main scoring functions are BD, BIC

and MI [95]. BIC score is introduced into the K2 algorithm to calculate the relevance among the factors, scores of each link and scores for each factor. The stability of relevance is proportional to the score. Under normal circumstances, China's NIMBY crisis transformation process requires that each step can get the best effect to achieve the short path, smooth and rapid overall effect. Therefore, K2 algorithm can be adopted to figure out the paths from PL to SSR and RM and those backward as well. In general, short NIMBY crisis transformation paths get rapid effects, but these are not stable. On the contrast, long NIMBY crisis transformation paths get stable effects but with high expenditure and halfway risk.

Regarding scores for each factor, they represent the influence weight on the Bayesian network. If one only reads the results of Table 1, it is easy to conclude that the influence of these 14 factors on the structure of the Bayesian network is divided into three levels. This shows that publicity and education, public participation, the rule of law, benefit compensation and project location can effectively realize the NIMBY crisis transformation. The impact of public decision, public attitude, multiple governance and negotiation on the NIMBY crisis transformation was not significant. Public risk perception and information publicity had no substantial significance for the NIMBY crisis transformation.

In the top-down routes from PL to SSR of Bayesian simulation I, there were five shortest routes, which were PL→PRP→PA→PP→SSR (Score = 113.95), PL→PE→RL→PP→SSR (Score = 159.87), PL→PE→RL→PD→SSR (Score = 156.56), PL→BC→RL→PP→SSR (Score = 166.89) and PL→BC→RL→PD→SSR (Score = 163.58). Among them, the route of PL→BC→RL→PP→SSR (Score = 166.89) had the highest score, which means this inference path was more stable than the other four paths. If the government wants to quickly realize the NIMBY crisis transformation in the short term, this path would be a better choice. It is attributed to the fact that selection of the project site, benefit compensation, the rule of law and public participation were implemented.

Similarly, it was found that PL→PE→BC→RL→PP→SSR (Score = 204.23), PL→PRP→PA→PE→RL→PP→SSR (Score = 185.49) and PL→PRP→PA→PE→BC→RL→PP→SSR (Score = 229.85) had the highest score among the paths of the same length. PL→PE→BC→RL→PP→SSR (Score = 204.23) was shorter and more stable than PL→PRP→PA→PE→RL→PP→SSR (Score = 185.49). The government could directly abandon PL→PRP→PA→PE→RL→PP→SSR (Score = 185.49). PL→PRP→PA→PE→BC→RL→PP→SSR (Score = 229.85) was usually stable as a result of high score among all paths, but with low efficiency. If the government wants to steadily resolve NIMBY crisis in the long run, this path would be a better choice, because public education is a long-term commitment of government to create strong environmental consciousness among all stakeholders [41]. Overall, the findings illustrate that PL→BC→RL→PP→SSR (Score = 166.89), PL→PE→BC→RL→PP→SSR (Score = 204.23) and PL→PRP→PA→PE→BC→RL→PP→SSR (Score = 229.85) were superior paths for the government to maintain social stability.

PL, BC, RL and PP existed in the three superior paths for the government to maintain social stability, and their Bayesian node scores were high, once again demonstrating that PL, BC, RL and PP play an important role in maintaining social stability. In the superior routes, crisis transformation for MSWI was realized in the order of BC→RL→PP. It is reasonable to infer that China resolves NIMBY crisis in accordance with the following policy implementation. Firstly, implementing the "Buy-Compensate-Balance" (BCB) mechanism relies on market purchase to share the cost of the residents around the MSWI facility. Secondly, the implementation of "Decide-Law-Trust" (DLT) mechanism requires legal thinking to enhance public trust in government. Finally, the public-centered "Communicate-Participate-Corporate" (CPC) mechanism is expected.

In top-down routes from PL to MR, PL→PE→RM (Score = 72.40), PL→BC→RL→RM (Score = 124.66), PL→PE→BC→RL→RM (Score= 162.00) and PL→PRP→PA→PE→BC→RL→RM (Score = 187.62) were the better ways to help to improve the quality of risk management in the government. Furthermore, on the one hand, PE could directly arouse RM in an independent way. On the other hand, by comparing PL→BC→RL→RM (Score = 124.66) and PL→PE→BC→RL→RM (Score = 162.00), only PE was brought in the path, but the score increased significantly. This illustrates that MR depended to

a large extent on PE. PE is a method on risk management to avoid risks and to protect the target from negative effects.

It is also worth mentioning that PE is a bridge factor with more degrees, which indicates that the impact of PE in the NIMBY crisis transformation for MSWI cannot be overlooked. Public knowledge is a vital factor influencing public awareness of why, what and how the MSWM system is implemented [96]. Therefore, strengthening publicity and education can increase the public's recognition and resolve the NIMBY crisis [97].

There was a causal relationship between information publicity and NIMBY conflict, which is consistent with the conclusions of many scholars. However, a great many government departments are reluctant to disclose real information [20]. Information publicity can be a double-edged sword. It can enhance transparency and reduce information asymmetry between government or enterprise and the public. Moreover, information publicity also has a negative effect on crisis transformation. Local residents do not have the expertise, time or energy to evaluate information provided by public sectors, with the result that information publicity provides users with the illusion of openness. This in turn acts to augment to an extreme the danger of NIMBY conflicts.

4. Discussion

4.1. Comparative Analysis

In Figure 3, NG did not appear in the reachable path to achieve the NIMBY crisis transformation for MSWI. The effectiveness of benefit compensation is still being debated in academic and policy-making arenas, because in some scholars' view, not all benefit compensation is helpful for resolving NIMBY crisis [65]. When the program is not properly set or the information is not made public, often communities do not accept either monetary or community gain offers willingly [97]. Thus, Table 2 and Figure 4 were obtained by adjusting the Bayesian calculus input order of the factors.

As shown in Table 2, the Bayesian score of BC had fallen and the Bayesian score of NG had increased, which has a great influence on the structure of the Bayesian network. Bayesian score of other factors did not change or changed slightly.

In Figure 4, the superior paths from PL to SSR were PL→PE→RL→PD→SSR (Score = 156.03), PL→PE→MG→RL→PD→SSR (Score = 186.06) and PL→PRP→PA→PE→MG→RL→PD→SSR (Score = 210.98). The score was lower than the superior paths of the same length in Figure 3, illustrating that the paths from PL to SSR in Figure 4 was not better than that in Figure 3. At this point, BC no longer appeared in the superior path, PD replaced the location of PP and MG began to play its role. When the government no longer pays attention to the benefit compensation for public, it is necessary to take measures such as community governance in order to effectively achieve the NIMBY crisis transformation. Both academics and practitioners have stressed that community participation in MSWI management should be an effective strategy to improve public acceptance towards locally unwanted land uses (LULUs) [31]. Meanwhile, this also suggests that economic compensation can maintain the environmental welfare of residents. For example, tax relief or a reduction of utility bills is widely regarded as an effective solution to the NIMBY protests [96].

The path of the same length from PL to MR was not superior to that in Figure 3. The score of PL→PRP→PA→MG→RL→RM (Score = 135.23) increases significantly, mainly because of the increased correlation between PA and MG. MG can change people's attitudes toward MSWI facilities, and personal participation in the management of MSWI plants contributes to increase their confidence in government or enterprises [98]. The realization of multiple governance can consider the introduction of social capital, such as the Public-Private-Partnership (PPP) project. Social capital is mainly responsible for the design, construction, operation and maintenance of the project, and the government departments are responsible for supervising the price and quality of the project to ensure the maximum social benefits of the PPP project [99,100].

Compared with Figure 3, PL→PRP→PA→PP→RL→PD→SSR (Score = 177.64) was added from the PL to SSR path, mainly because the causality between PP and RL changed. PP became the parent node of the RL. PP and PD appeared in the same path. It is recommended that the government should take into account the public participation right and make the public get sufficiently psychological compensation when the benefit compensation is not enough.

The impact of IP on the NIMBY crisis transformation for MSWI has not changed. Studies conducted have reported the information publicity to reduce the negative impact of NIMBY facilities, so as to eliminate the public's concerns and prevent NIMBY conflict, which is different from China's situation. Information disclosure is limited in the project environmental impact assessment, site selection and even construction, thus have few impacts on increasing residents' acceptance. The government organizes a meeting with some companies' managers before the construction and requests the participants to sign a consent form after the meeting. But the information disclosure in the meeting did not cover details about the environmental and social influence of MSWI [97].

Although NG becomes the parent node of BC, it still does not appear in the path from PL to SSR or MR. The way the government negotiates with the public does not take into account the needs of local residents, which leads to the opposition of the residents [101]. Furthermore, the NIMBY crisis is hard to transform when the government only communicates with the people and gives them certain benefit compensation.

4.2. Considerations of Main Factors in Transformation Paths

As described above, the main factors for the NIMBY crisis transformation path in China could be the project location, benefit compensation, publicity and education, public decision, public participation, multiple governance and rule of law. However, the impacts from each factor may change along with economy growth and technology innovation.

4.2.1. Project Location

Citizens' tolerance for environmental risks in general has been declining even as their overall health and economic well-being have increased [10]. A MSWI facility may degrade quality of life in the host community, that is, some impacts are easily perceived, such as increased traffic, noise and odor, as well as the presence of toxic waste and emissions. There is a gradient of perceived risk associated with MSWI facilities wherein attitudes toward the siting are related to the distance away from one's home or community, perception of odor and visibility from residential areas, so in the phase of site selection, certain public groups may already fight against the project because of their perceived risks. In response to these challenges in project location, modern waste management should examine technical efficiency to improve incinerator quality and safety in terms of environmental protection. It stands to reason that increase investment in research and development of advanced waste incineration technology because of its reducing probability of NIMBY crisis exposures mainly through prior control.

4.2.2. Benefit Compensation

In China, MSWI facilities are generally located in remote areas or suburbs where are relatively poor. Therefore, reasonable benefit compensation is effective in minimizing a NIMBY reaction for MSWI. Such is the case, this approach has been followed in China, and continues to be used today. For a conflict-resolution to be successful, it is important to foster not only economic aspects but also long-term ecological benefits, social benefits and to take into account the needs of the people [102]. This study suggests that the following commitments may be included as a form of compensation package: Health and safety protection, economic subsidies, employment opportunities creation or support for necessary services such as transportation and education.

4.2.3. Publicity and Education

The NIMBY syndrome seems to have the strongest effect in areas where there is no or very little knowledge about NIMBY facilities [103]. After plenty failed MSWI projects, general lack of knowledge attracts an increasing attention of the government. Knowledge is the first necessary condition to solve the NIMBY problem and the basis of participation [104]. The effectiveness of publicity and education is affected by many economic-societal factors, such as personal behavior in terms of reading newspapers and books, watching TV and using the internet. It is important to notice that the ways to implement publicity and education need to be specific, and their contents and timing should be well planned. It allows for the content of argument among different stakeholders is not whether to build the MSWI facilities or not, but how to process MSW properly and economically.

4.2.4. Public Decision

With regards to public decision, many scholars believe that different stakeholders should be incorporated in the decision-making process because only through their participation can important information about residents' preferences and local conditions be delivered to the decision-makers and can residents' concerns receive an adequate response [105,106]. But it is a common phenomenon that the government fails to engage the public substantially at the decision-making stage [97]. The nearby residents are not satisfied to just be "involved", or put it more accurately, "informed", about the decision at this moment. Often this means that the public either have been excluded from decision-making or involved too late [106]. They desire to actively step in the decision-making arena. Thus, when this measure is adopted to transform the NIMBY crisis for MSWI, it further argues that different societal forces should be included and a wider variety of opinions should be heard. Another important aspect relating to the content of public decision is that a more inclusive decision process can be designed on the basis of explicit or implicit rules about who to involve in each stage of the process and on what basis they should be involved.

4.2.5. Public Participation

Public participation is considered a reasonable strategy to involve the public interests in resolving NIMBY conflicts [107]. Without effective engagement, negative perceptions of a new project can spread quickly so public involvement is a central concern for urban planners. The continuous improvement of a series of systems such as the electoral system, appeal system, hearing system and inquiry system, as well as the launch of the mayor's hotline and leadership reception day, have enabled the public to have extensive participation in form but the public's influence on public affairs is still very limited because public participation is complex since it needs to be adapted to the local culture and social norm to solve the specific NIMBY problem. Achieving substantive public participation requires government guidance and regulation. Therefore, the scientific arrangement of the participants, topic for discussion, procedures and scope is the necessary link to ensure the substantive participation of the public and public participation is not only essential at the site selection stage, but also should contribute to the construction, operation and abandonment stage to help decision-makers establish the most apposite solutions satisfying the broad interests of society [32].

4.2.6. Multiple Governance

Collaborative governance is one potential solution to address the NIMBY mentality, where conflicts take place [108] and MSWM is one system project that incorporated various participants of society. The government should play the role of administrative management, market management, social management and public management, and introduce the multiple government mechanism to resolve the NIMBY crisis. The active participation of public organizations and groups contribute to the resolution of NIMBY conflict problems [109]. Meanwhile, allowing the community to be involved

in governance aids in solving the NIMBY problem creatively, and encouraging the achievement of effective negotiations [110]. Nevertheless, practices of multiple governance need time.

4.2.7. Rule of Law

At present, China does not have a legal norm that specifically resolves environmental conflicts [65]. And the legal provisions for specifically solving the problem of MSWI facilities siting are not well formulated or implemented [111]. As a result, a growing body of homeowners seeks to have their voices heard through non-legal channels, which may give rise to noninstitutionalized action such as protests and demonstrations. In general, the rule of law has huge potential to be further developed, because only the law can establish a long-term stable trust relationship between the public and the government [112]. The legislative regulation on the principles, requirements, procedures, and compensation for the location of NIMBY facilities is beneficial to enhancing the confidence of the people [70], which is the cornerstone of the NIMBY crisis transformation for MSWI.

The conditions that NIMBY facilities may lead to land-use conflicts are still widespread in many countries today. Figures 3 and 4 provide greater practicality for the NIMBY crisis transformation for MSWI in developing countries. It serves to heighten awareness of the relationships involved in the NIMBY crisis transformation.

5. Conclusions

Waste treatment is the core mean to reach the MSWM objectives including protection of human health and environment, economic development, and fulfillment of social and regulatory requisites. Incineration is such a waste disposal way. A lack of effective steps to address local opposition is likely to cause project relocation, indefinite postponement and even cancellation. In recent years, a growing body of literature has discussed how to solve the NIMBY crisis. However, few studies have explored it from the perspective of crisis transformation. Thus, the study is set out with the overall aim of providing theoretical underpinning for attempts to understand the NIMBY crisis transformation in China.

The evidence generated here presents the instance of comprehensive academic research on NIMBY crisis transformation for MSWI. By application to the co-word analysis approach, the objective and novel data types from literature was extracted. Then, with reference to the Bayesian theory, this study provided evidence from the ground up that could foster thinking among the governments in China with regard to how they could possibly find a superior implementation path to resolve the NIMBY crisis for MSWI. Finally, a framework was developed for analyzing and interpreting the process of the NIMBY crisis transformation.

Our study findings showed that it was clear that PL, BC, PE, PD, PP, MG and RL had a positive impact on the NIMBY crisis transformation for MSWI in China, and the impact of PL, BC, RL and PP seemed to be stronger. PE was a bridge factor with more degrees. This implies that the government alike should pay greater attention to PE, especially in a long-term commitment. PD and MG have a potential breakthrough for transforming the NIMBY crisis but NG and IP have no substantial significance for the NIMBY crisis transformation in China's current context. Perhaps with economy growth and technology innovation, the impacts from each factor may change. Finally, on the basis of the above analysis, the study highlights what should be paid extra attention to when implementing relevant measures. Careful consideration of these factors establishes the premise for the NIMBY crisis transformation and the benefits of optimizing the transformation path in different decision contexts.

The main contribution of this study is that the proposed analysis framework of crisis transformation and the Bayesian network can potentially be used to resolve other types of conflicts involving environmental considerations. Applying the framework to the NIMBY crisis helps to identify both dangers and potential opportunities in environmental conflict resolution and thus to suggest ways of improving such resolution processes in the future.

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Appendix A

Table A1. Initial word-context matrix.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
PL	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
PRP	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
PA	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0
NC	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
RL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PD	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
NG	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
PE	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
PP	0	0	1	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	1
IP	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
MG	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
BC	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
SSR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RM	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
	21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
PL	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0
PRP	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
PA	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
NC	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1	0	1
RL	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0
PD	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PE	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
PP	0	0	0	0	0	1	1	0	0	0	0	0	1	1	1	1	0	1	0	1
IP	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
MG	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
BC	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
SSR	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
RM	0	0	1	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
	41	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**		
PL	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0		
PRP	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
PA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
NC	0	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1		
RL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
PD	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0		
NG	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0		
PE	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0		
PP	1	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0		
IP	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
BC	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1		
SSR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1		
RM	0	1	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0		

Appendix B

Table A2. The meaning of all the acronyms.

Acronyms	Meaning	Acronyms	Meaning
NIMBY	Not In My Back Yard	PA	Public Attitude
MSW	Municipal solid waste	NC	NIMBY Conflict
MSWI	Municipal solid waste incineration	BC	Benefit Compensation
MSWM	Municipal solid waste management	PP	Public Participation
CNKI	China National Knowledge Infrastructure	PE	Publicity and Education
SVD	Singular value decomposition	PD	Public Decision
LULUs	Locally Unwanted Land Uses	MG	Multiple Governance
PPP	Public-Private-Partnership	NG	Negotiation
BCB	Buy-Compensate-Balance	RL	Rule of Law
DLT	Decide-Law-Trust	IP	Information Publicity
CPC	Communicate-Participate-Corporate	SSR	Social Stability Risk
PL	Project Location	RM	Risk Management
PRP	Public Risk Perception		

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