Hindawi
Mathematical Problems in Engineering
Volume 2018, Article ID 5213504, 17 pages
https://doi.org/10.1155/2018/5213504

Research Article

Site Selection of Waste-to-Energy (WtE) Plant considering Public Satisfaction by an Extended VIKOR Method

Yunna Wu,[1,2] Lei Qin ,[1,2] Chuanbo Xu,[1,2] and Shaoyu Ji [1,2]

[1] *School of Economics and Management, North China Electric Power University, Beijing, China*
[2] *Beijing Key Laboratory of New Energy and Low-Carbon Development (North China Electric Power University), Changping, Beijing 102206, China*

Correspondence should be addressed to Lei Qin; frankqin736116659@163.com

Received 7 May 2018; Revised 23 September 2018; Accepted 28 October 2018; Published 8 November 2018

Academic Editor: Oliver Schütze

Site selection of waste-to-energy (WtE) plant is critically important in the whole life cycle. Some research has been launched in the WtE plant site selection, but there is still a serious problem called Not In My Back Yard (NIMBY) effect that needs to be solved. To solve the problem, an improved multigroup VIKOR method is proposed to choose the optimal site and compromised sites. In the proposed method, the public satisfaction is fully considered where the public is invited as an evaluation group far more than creating general indicators to represent the public acceptance. First of all, an elaborate criteria system is built to evaluate site options comprehensively and the weights of criteria are identified by Analytic Hierarchy Process (AHP) method. Then, the interval 2-tuple linguistic information is adopted to assess the ratings for the established criteria. The interval 2-tuple linguistic ordered weighted averaging (ITL-OWA) operator is utilized to aggregate the opinions of evaluation committee while the opinions of the public are aggregated using weighted average operator. Finally, a case from south China which shows the computational procedure and the effectiveness of the proposed method is proved. Last but not least, a sensitivity analysis is conducted by comparing the results with different weights of evaluation group assessments.

1. Introduction

In recent decades of China, more and more wastes are piled up around cities which not only damage the environment but limit the urban development. The clearance volume of life waste in China is shown as Figure 1 over past decade, and it has become a thorny problem to dispose these municipal solid wastes. As one of three garbage disposal methods in addition to security landfill and garbage compost, waste incineration has the most obvious effect in reducing the volume and quantity of garbage [1]. Moreover, it does less harm to the environment from a long-term perspective compared with security landfill and can be used in most areas which is infeasible for garbage compost [2]. With above characteristics, waste incineration is the most suitable way to deal with garbage in China. And according to 13th Five-Year Plan of China, the capacity of daily average incineration will exceed 590 thousand tons, which means that the proportion of garbage incineration will exceed 50 percent in total waste removal by 2020. During the rapid development of the construction of waste incineration power plants, the site selection has become the critical problem in the whole project. And many unignorable factors of waste power generation project which may have an influence on surrounding residents [3], local environment, and even the operation and maintenance of WtE plant are not fully considered [4]. So, some projects need reevaluation or relocation due to inappropriate site selection methods [5].

In the evaluation process of waste-to-energy (WtE) site selection, there are mainly three problems that need to be solved. (i) In order to cope with special situations, the senior manager needs multiple feasible site selections in practical decision. The VIKOR (VIsekriterijumska optimizacija i KOmpromisno Resenje) method could not only choose the optimal site, but also supply the compromised sites [6]. (ii) During the process of gathering the assessments from respondents, it is usually difficult for one to accurately express personal preference. This problem will lead to information

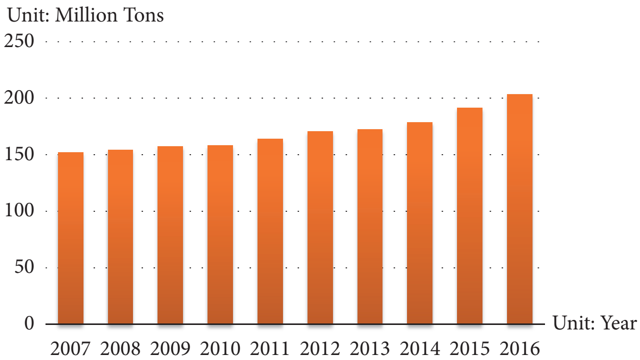

Figure 1: Clearance volume of life waste in China from 2007-2016 (Data source: National Bureau of Statistics of China).

distortion which results in choosing an unsatisfied alternative [7]. (iii) Different from other forms of power generation, it is technically feasible for the public to make appropriate judgement on WtE site selection problem and also necessary to obtain the recognition of surrounding residents [8].

With above problems, this study is going to supply a decision framework of WtE site selection. Considering the public satisfaction, the assessments for alternatives from the public must be gathered. During the process of gathering assessment information, it would be hard for many people to make a certain judgement about these decision factors of different alternatives. But the interval 2-tuple linguistic set allow evaluators to make a range judgement which ensure the integrity of the assessments. In the proposed decision framework, interval 2-tuple linguistic information is applied to make evaluation of each criterion when assessing different WtE site options by DMs (Decision Makers) to make the process of evaluation easier and reduce the probability of data distortion. Based on the assumption that the incidence relation between decision factors is so weak that it could be neglected, the AHP method is used to confirm the index weights owing to its universality.

Then we design a new VIKOR framework which aggregates the evaluation of experts group and the public to handle the WtE site selection problems. In the extended VIKOR method, multigroup evaluation has been considered where the most important change compared with the traditional VIKOR method is the integrating of (S,α) and (R,α) values from evaluation committee and the public. With ranking result of the extended VIKOR method, the optimal alternative and compromised alternatives are figured out at the time satisfying the public.

The main contributions of this work can be summarized: (1) Firstly, the established evaluation system takes the public satisfaction into account by turning the public into one of the decision makers, which can help solve the NIMBY problem through full investigation. (2) Secondly, the extended VIKOR method can integrate the results of different evaluation groups with significant backgrounds, by endowing different weights to eliminate the evaluation deviation in the integrated result. (3) Finally, the method proposed could enrich the evaluation study system to certain extent where the validity and the feasibility of the way combining different methods at different stages are proved in this study.

The remainder of this paper is organized as follows. Section 2 reviews the main advantages and application of the VIKOR method. A whole criteria framework is established and the decision factors are explained in Section 3. In Section 4, basic notions of interval 2-tuple linguistic information and the VIKOR method are introduced. Section 5 describes the procedure of WtE site selection in this study and shows the decision framework through a case study in Section 6. Section 7 discusses the computing result and makes a sensitivity analysis. Conclusion of this study and recommended further study direction are put forward in last section.

2. Literature Review

As a MCDM problem, the decision results of WtE plant site selection are affected greatly by the evaluation methods. There are some basic MCDM methods widely used, such as Analytic Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Elimination et Choix Traduisant la Realité (ELECTRE), Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE), VIKOR, and other improved methods based on above methods including Fuzzy Analytic Hierarchy Process (FAHP), ELECTRE-II, ELECTRE-III, and so on [9–16]. Sennaroglu and Varlik Celebi [17] applied AHP integrated PROMETHEE and VIKOR methods to select the optimal military airport location. Wu et al. [18] used ELECTRE-III method to decide the offshore wind power station site. A VIKOR-based fuzzy multicriteria decision making method is developed to assess different healthcare waste disposal methods [19].

Different from other ranking methods, the VIKOR method has two main advantages. The first advantage is that the VIKOR method finds out the optimal alternative based on maximum group utility and minimum individual regret [20, 21]. The second is that compromised solution can be supplied in the ranking result fulfilling the practical needs [22]. As the WtE power plant is part of urban infrastructure, the construction and the operation need to meet the requirements of all aspects. In other words, the WtE power plants need to ensure the performance of every decision factor. And the VIKOR method is sourcing from the consideration of maximum group utility and minimum individual regret to find out the optimal alternative. So, the VIKOR method could fit for the WtE site selection problem well.

The VIKOR method has been widely used in group decision making problems. The application of VIKOR method in existing studies could be roughly divided into three kinds which are (i) combining with index assignment method in the environment with uncertain criterion evaluation, (ii) changing some steps of the VIKOR method to adapt to a special assessment environment, (iii) combining the result with other similar methods to get a comprehensive evaluation result. For the first kind of application, the role of the index assignment method is a supplement to the VIKOR method in the evaluation stage. The index assignment method could convert the description of index assessment into quantitative data which is the basis of VIKOR application. There are many methods to describe the assessment of DMs, such as fuzzy numbers [23], linguistic information [7, 24], linguistic hesitant fuzzy information [25, 26], triangular intuitionistic fuzzy numbers [27], 2-tuple linguistic information [28], interval 2-tuple linguistic information [29, 30], and so on. Among above index assignment methods, the interval 2-tuple linguistic information is adopted to evaluate the WtE site selection criteria in this study. Thus, it would be easier to understand and operate for evaluators especially the public, which will ensure the authenticity of the evaluation result to site selection indexes under uncertain language environment [7]. This advantage could solve the problem well as the result of the public evaluation has great instability owing to inadequate expertise.

Some studies have adjusted the method steps under specific environment. One way is to add steps to the traditional one. To evaluate the potential zones for ore occurrences in the region of interest, Abedi et al. [6] had defined the mineral potential mapping values M_i based on the Q_i values where $M_i = (Q^+ - Q_i)/(Q^+ - Q^-)$. The other way is to change the parameters in the definition equations of the traditional VIKOR method. Considering the decision maker's attitude toward risk, Tavana et al. [31] had redefined the f_i^+ and f_i^- values based on risk seeking attitude and risk converse attitude with the coefficients of variation cv_{ij} to get different attitude outranking results. Similarly, this study gives the definition of collective results S_i and R_i with the weight λ representing the importance of evaluation committee assessment under multigroup evaluation existing obvious distinction between each other.

As for the combination of different MCDM methods, the studies could be divided into two main kinds called parallel combination and concatenate combination according to the relation of adopted methods. In the way of parallel combination, the MCDM methods have no changes in the steps. And the main benefit is that the application of different MCDM methods could be very helpful to sensitivity analysis by comparing the outranking results [32, 33]. Distinguished from parallel combination, the way of concatenate combination integrates the advantages of different MCDM methods by intercepting some of the steps of the methods which is on the premise that the procedure is feasible and the result is reasonable [34]. For example, the VIKOR method could mitigate the problem that ELECTRE I could only provide partial ranking [35].

To solve the NIMBY problem in the site selection of WtE plants, the public are invited to evaluate the indicators of different site options in this study. The application of interval 2-tuple linguistic information makes the evaluation of the public credible and effective. And the improved VIKOR method could not only solve the multigroup assessments problem, but adapt to different evaluation backgrounds by assigning different weights to the evaluation group.

3. Analysis on the Decision Factors of the WtE Plant Site Selection

On account of high investment, WtE sites are unchangeable economically, and the factors related to site selection of the WtE plant must be as comprehensive and complete as possible. Combining plenty of literature contents and relevant document data, four kinds of perspectives of the WtE plant site selection can be summarized: business operation, government intervention, natural environment, and social influence. Besides, factors from the perspective of business operation include production factors and land factors, while factors from the perspective of natural environment are divided into natural factors and environment factors in this article.

The attributes considered for site selection of the WtE plant are as follows: (1) production factors, (2) land factors, (3) policy factors, (4) natural factors, (5) environment factors, and (6) social factors.

3.1. Production Factors. Production factors will be considered most in the economic feasibility. Construction cost and operation and maintenance costs directly determine the efficiency of investment and payback period. Waste supply which includes transportation distance of waste, low heat value of waste, and combustion quality of waste (refers to corrosive characteristics to incinerators) has a great influence on technological process and daily running costs [36–38]. Considering that waste disposal needs water, long distance of water supply will greatly increase the transportation costs. Similarly, long power transmission distance means high line loss, and it is positively associated between distance to the main road and transportation costs of other materials [39].

3.2. Land Factors. In this paper, the land factors refer to factors related to waste plant investment especially [40]. Due to bigger investment than landfill plant, the refuse incineration power plants are usually seen in the economically developed cities. Thus, land purchase is vital as one of the primary consideration factors for investors. In addition, the distance to the residential area from refuse incineration power plant should not only be in accordance with rules published, but get the permission of residents nearby [41].

3.3. Policy Factors. With the characteristics of high risk, low-income, and high environmental return comparing to landfills, the WtE plants rely on the financial support of government greatly [42]. As far as refuse incineration power generation is concerned, there are mainly three ways to encourage the business: high feed-in tariff, tax preferences, and waste disposal subsidy [43]. Higher feed-in tariff than normal coal-fired power price can increase the plants' revenue by more than 30 percent. And tax preferences can cut down the costs greatly, for instance, a refundable value-added tax of 17 percent. Moreover, the WtE plant operators can get waste disposal subsidy based on the amount of waste disposed from the local government.

3.4. Natural Factors. Theoretically, the WtE plants have no limited service life. Since the natural condition could affect the procedure of municipal solid waste, the WtE plants site selection must take natural factors into consideration [44]. Wind condition determines the range and strength of pollutant gas from the WtE plants. For example, if the WtE plant locates in the downwind of the annual leading wind direction, the pollutant gas can reach further areas, and it means the higher risk of gas leakage accidents [45]. To avoid unnecessary loss caused by flood disaster, investigating local hydrological condition is essential. Also, the WtE plant sites selected should be constructed far away from seismically active regions and experts should make seismic evaluation and take precautions against earthquakes to decrease the earthquake damage.

3.5. Environment Factors. Environmental factors contain three different aspects: resource environment, living environment, and ecological environment, respectively [46, 47]. Firstly, comparing to landfills, refuse incineration can decrease the volume of waste by 80 percent. And the waste residual just needs to occupy little land areas. With the power generated from refuse incineration, the requirement of coal-fired power which needs coal mining will reduce correspondingly. Some of the waste residual can be used for construction and roadbed which save large amounts of clay. Then, when it comes to the influence on living environment, the construction of the WtE plants can bring the problem of noise and stink as well as air pollution to local residential, but it has a positive effect on pollutant discharge reduction such as reducing carbon dioxide. Finally, the construction and operation of the WtE plants will have an inevitable impact on local ecosystem. So, the influence on local ecological environment should be taken into consideration.

3.6. Social Factors. In practice, the biggest barrier in constructing the WtE plants is from the popular protests and the phenomenon of NIMBY effect [48, 49]. It is necessary to think about the social factors which reflect the willingness of local residents to accept the construction and operation of a WtE plant. Before getting the permission of local residents, the WtE plants will not be built. Good coordination with nearby industries can reduce the construction and operation cost of the WtE plants efficiently. For instance, it can save considerable transportation cost when the site is next to construction industry. And under the condition that the construction and operation of WtE plants can improve the employment and local economy, more obvious the effect is, more support the WtE plants will get from the local residents [50].

In conclusion, in order to make the optimal site selection among alternatives, six kinds of decision factors should be considered as shown in Table 1.

4. Interval 2-Tuple Linguistic Information

The 2-tuple linguistic representation model is initiated by Herrera and Martinez [51] based on the concept of symbolic translation. It is used for representing the linguistic evaluation information by means of a 2-tuple (s, α), where s is a linguistic label from predefined linguistic assessment set S and α represents a possible value for a linguistic variable. For overcoming the restriction of the Herrera and Martinez model, Tai and Chen [52] proposed a generalized 2-tuple linguistic model to deal with multigranular linguistic term sets.

Definition 1 (see [52]). Let $S = \{s_i \mid i = 0, 1, 2, \ldots, g\}$ be a linguistic term set with granularity $g+1$ and $\beta \in [0, g]$ a value representing the result of a symbolic aggregation operation; then the 2-tuple that expresses the equivalent information to β is obtained with the following function:

$$\Delta : [0, g] \longrightarrow S \times [-0.5, 0.5) \tag{1}$$

$$\Delta(\beta) = (s_i, \alpha), \quad \text{with } \begin{cases} s_i, & i = round(\beta) \\ \alpha = \beta - i, & \alpha = [-0.5, 0.5) \end{cases} \tag{2}$$

where s_i has the closest index label to β and α is the value of the symbolic translation.

Definition 2 (see [51, 52]). Let $S = \{s_i \mid i = 0, 1, 2, \ldots, g\}$ be a linguistic term set and (s_i, α_i) be a 2-tuple. There exists a function Δ^{-1}, which is able to convert the 2-tuple linguistic information into its equivalent numerical value $\beta \in [0, g]$. The reverse function Δ^{-1} is defined as follows:

$$\Delta^{-1} : S \times [-0.5, 0.5) \longrightarrow [0, g] \tag{3}$$

$$\Delta^{-1}(s_i, \alpha) = i + \alpha = \beta \tag{4}$$

It is noteworthy that the conversion of a linguistic term into a linguistic 2-tuple consists of adding a value 0 as symbolic translation:

$$i \in S \Longrightarrow (s_i, 0) \tag{5}$$

Definition 3 (see [51]). Let (s_k, α_1) and (s_l, α_2) be two 2-tuples; then:

(1) if $k < l$ then (s_k, α_1) is smaller than (s_l, α_2);

(2) if $k = l$ then

(a) if $\alpha_1 = \alpha_2$ then (s_k, α_1) is equal to (s_l, α_2);

(b) if $\alpha_1 < \alpha_2$ then (s_k, α_1) is smaller than (s_l, α_2);

(c) if $\alpha_1 > \alpha_2$ then (s_k, α_1) is bigger than (s_l, α_2).

Definition 4 (see [53]). Suppose a linguistic term set $S = \{s_i \mid i = 0, 1, 2, \ldots, g\}$. An interval-valued 2-tuple is composed of two linguistic terms and two numbers, denoted by $[(s_i, \alpha_1), (s_j, \alpha_2)]$, where $i \le j$, s_i (s_j) and α_1 (α_2) represent the linguistic label of the predefined linguistic term set S and symbolic translation, respectively. An interval-valued 2-tuple linguistic variable can be converted into an interval value $[\beta_1, \beta_2]$ $(\beta_1 \le \beta_2)$ as follows:

Table 1: Decision factors for site selection WtE plants.

Decision factors	Index	Sub-index	Criteria type
(C_1) Production factors	(C_{11}) Construction and maintenance costs	(a_1) Average construction cost (CNY/kW)	Cost
		(a_2) Average operation and maintenance cost (CNY/kW)	Cost
	(C_{12}) Waste supply	(b_1) Transportation distance of waste (km)	Cost
		(b_2) Low heat value of waste (kJ/kg)	Benefit
		(b_3) Combustion quality of waste	Cost
	(C_{13}) Water supply distance (km)		Cost
	(C_{14}) Power transmission distance (km)		Cost
	(C_{15}) Distance to the main road (m)		Cost
(C_2) Land factors	(C_{21}) Land price (CNY/m2)		Cost
	(C_{23}) Distance to the residential area (m)		Benefit
(C_3) Policy factors	(C_{31}) Feed-in tariff (CNY/kWh)		Benefit
	(C_{32}) Tax preferences		Benefit
	(C_{33}) Waste disposal subsidy (CNY/t)		Benefit
(C_4) Natural factors	(C_{41}) Wind conditions		Benefit
	(C_{42}) Hydrologic condition		Benefit
	(C_{43}) Geological condition		Benefit
(C_5) Environment factors	(C_{51}) Resource environment	(d_1) Land saving (m^2/a)	Benefit
		(d_2) Energy savings: standard coal (t/a)	Benefit
		(d_3) Clay savings (t/a)	Benefit
	(C_{52}) Living environment	(e_1) Noise pollution and stink pollution	Cost
		(e_2) Air pollution	Cost
		(e_3) Pollutant discharge reduction (t/a)	Benefit
	(C_{53}) Ecological environment		Cost
(C_6) Social factors	(C_{61}) Acceptance of residents		Benefit
	(C_{62}) Coordination with nearby industries		Benefit
	(C_{63}) Improving the employment and local economy		Benefit

$$\Delta(\beta_1,\beta_2) = [(s_i,\alpha_1),(s_j,\alpha_2)],$$

$$\text{with} \begin{cases} s_i, & i = round(\beta_1) \\ s_j, & j = round(\beta_2) \\ \alpha_1 = \beta_1 - i, & \alpha_1 = [-0.5, 0.5) \\ \alpha_2 = \beta - j, & \alpha_2 = [-0.5, 0.5) \end{cases} \quad (6)$$

On the contrary, there is always a function Δ^{-1} such that an interval 2-tuple can be transformed into an interval value $[\beta_1, \beta_2]$ ($\beta_1, \beta_2 \in [0, g]$) as follows:

$$\Delta^{-1}[(s_i,\alpha_1),(s_j,\alpha_2)] = [i+\alpha_1, j+\alpha_2] = [\beta_1,\beta_2] \quad (7)$$

In particular, if $i = j$ and $\alpha_1 = \alpha_2$, then $[(s_i, \alpha_1), (s_j, \alpha_2)]$ reduces to a 2-tuple linguistic variable.

Definition 5 (see [54]). For an interval-valued 2-tuple $Q = [(s_i, \alpha_1), (s_j, \alpha_2)]$, its score function is expressed by the following formula:

$$S(Q) = \frac{(\beta_1+\beta_2)}{2} = \frac{[(i+\alpha_1)+(j+\alpha_2)]}{2} \quad (8)$$

The score function is regarded as a basis to compare two interval-valued 2-tuples. For two interval-valued 2-tuples, the one with a larger score function corresponds to a larger interval-valued 2-tuple. However, it is really possible that two different interval-valued 2-tuples may have an identical score value. In that event, accuracy function should be brought into consideration.

Definition 6 (see [53]). For an interval-valued 2-tuple $Q = [(s_i, \alpha_1), (s_j, \alpha_2)]$, its accuracy function is expressed by the following function:

$$H(Q) = (j+\alpha_2) - (i+\alpha_1) \quad (9)$$

It is obvious that $0 \le H(Q) \le g$. For two interval-valued 2-tuples with the same score function, the smaller the accuracy function, the larger the corresponding interval-valued 2-tuple.

To sum up, the procedure to compare any two interval-valued 2-tuples is listed as follows.

Let $Q_1 = [(s_{i_1}, \alpha_1), (s_{i_1}, \alpha_2)]$ and $Q_2 = [(s_{i_2}, \alpha_1'), (s_{j_2}, \alpha_2')]$ be two interval 2-tuples:

(1) If $S(Q_1) > S(Q_2)$, then $Q_1 > Q_2$.

(2) If $S(Q_1) < S(Q_2)$, then $Q_1 < Q_2$.

(3) If $S(Q_1) = S(Q_2)$, then

(a) if $H(Q_1) > H(Q_2)$ then $Q_1 < Q_2$;

(b) if $H(Q_1) < H(Q_2)$ then $Q_1 > Q_2$;

(c) if $H(Q_1) = H(Q_2)$ then $Q_1 = Q_2$.

Definition 7 (see [55]). Let $X = \{[(s_{i_1}, \alpha_1), (s_{j_1}, \alpha_1')], [(s_{i_2}, \alpha_2), (s_{j_2}, \alpha_2')], \dots, [(s_{i_n}, \alpha_n), (s_{j_n}, \alpha_n')]\}$ be a set of interval 2-tuples and $\omega = (\omega_1, \omega_2, \dots, \omega_n)^T$ be their associated weights, with $\omega_k \ge 0$ and $\sum_{k=1}^{n} \omega_k = 1$. The interval 2-tuple weighted average aggregation (ITL-WAA) operator is defined as

$$\begin{aligned} & ITL-WAA\{[(s_{i_1},\alpha_1),(s_{j_1},\alpha_1')], \\ & [(s_{i_2},\alpha_2),(s_{j_2},\alpha_2')],\dots,[(s_{i_n},\alpha_n),(s_{j_n},\alpha_n')]\} \\ & = \Delta\left[\sum_{k=1}^{n}\omega_k\Delta^{-1}(s_{i_k},\alpha_k), \sum_{k=1}^{n}\omega_k\Delta^{-1}(s_{j_k},\alpha_k')\right] \end{aligned} \quad (10)$$

Definition 8 (see [55]). Let μ be a fuzzy measure where μ has the properties:

(1) $\mu(0) = 0$.

(2) $\mu(1) = 1$.

(3) $\mu(a) \ge \mu(b)$ if $a \ge b$.

And let $Q_m = [(s_{i_m}, \alpha_m), (s_{i_m}, \alpha_m')]$ $(m = 1, 2, \dots, n)$ be an interval linguistic variable. $(\sigma(1), \sigma(2), \dots, \sigma(n))$ is a permutation of $(1, 2, \dots, n)$, so that $Q_{\sigma(1)} \ge Q_{\sigma(2)} \ge \cdots \ge Q_{\sigma(n)}$. $F_{\sigma(0)} = \varnothing$ and for $i \ge 1$, $F_{\sigma(i)} = \{\omega_{\sigma(k)} \mid k \le i\}$. $\mu(F) = \sum_{k=1}^{\|F\|} \omega_k'$, where $\|F\|$ is the number of the elements in F, then $\omega_k' = \mu(F_{\sigma(k)}) - \mu(F_{\sigma_{(k-1)}})$, $i = 1, 2, \dots, n$. Thus, the ITL-WAA operator is reduced to the following interval linguistic 2-tuple ordered weighted averaging (ITL-OWA) operator.

$$\begin{aligned} & ITL-OWA(Q_1,Q_2,\dots,Q_n) \\ & = \Delta\left[\sum_{k=1}^{n}\omega_k'\Delta^{-1}(s_{i_k},\alpha_k), \sum_{k=1}^{n}\omega_k'\Delta^{-1}(s_{j_k},\alpha_k')\right] \end{aligned} \quad (11)$$

5. Decision Framework

Different from existing study, the opinion of the public is fully considered to solve the NIMBY problem at the stage of WtE site selection. A multigroup VIKOR method is constructed to take account of the public assessment. The decision framework of the proposed method for WtE site selection is shown as Figure 2.

Stage 1 (identifying alternatives and decision factors). In first stage, basic research of alternatives A_i $(i = 1, 2, \dots, m)$ figures out the evaluation objects which need be considered cautiously with its profound social influence. Judgement of the construction necessity and the feasibility of geographical conditions are two main preconditions for WtE plants establishment in the process of identifying alternatives. Moreover, decision factors C_j $(j = 1, 2, \dots, n)$ will be selected using Delphi method where expert groups are made up with senior managers, related research scholars, and programmers. Then, estimate the importance degree of correlation coefficient between factors using AHP method by expert group expressed as w $(w = (w_1, w_2, \dots w_j, \dots, w_n)^T)$.

Stage 2 (establish the decision matrix with experts and public in interval-valued 2-tuple linguistic). In this stage, information and data of criteria will be collected to make the

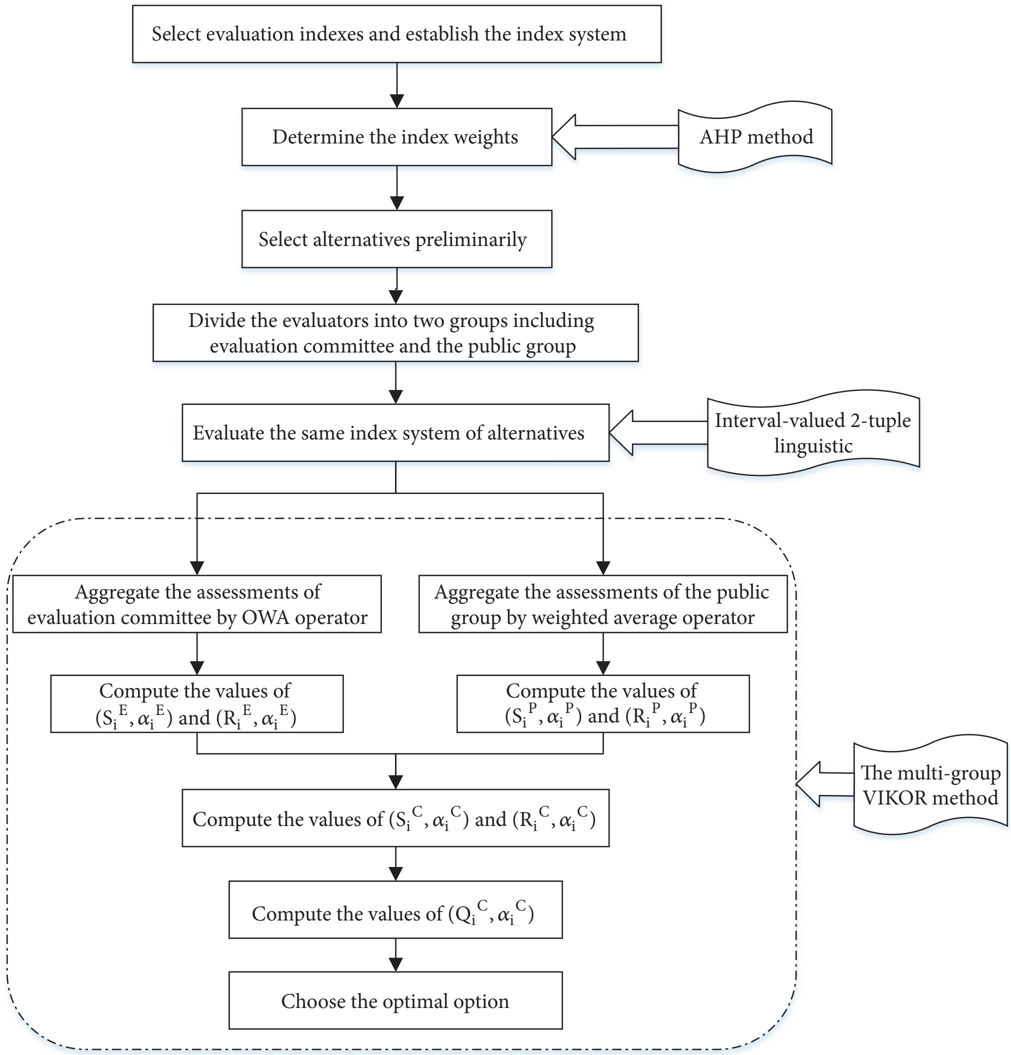

Figure 2: Decision framework of the proposed method for WtE site selection.

alternatives situation as detailed as possible. And quantitative values in the survey will be transformed into interval-valued 2-tuple linguistic and make up decision matrix with other criteria evaluations in interval-valued 2-tuple linguistic by experts group and the public group separately. The procedure of evaluation of alternative criteria in interval-valued 2-tuple linguistic is as follows:

Suppose that DM_k provides his assessments in a set of seven linguistic terms and the linguistic term set is denoted as

$$S = \{s_o : Extremely\ Low\,(EL)\,;\ s_1 : Very\ Low\,(VL)\,;\ s_2 : Low\,(L)\,;\ s_3 : Medium\,(M)\,;\ s_4 : High\,(H)\,;\ s_5 : Very\ High\,(VH)\,;\ s_6 : Extremely\ High\,(EH)\} \tag{12}$$

Based on given data and evaluation results given by experts group and public group, the value of alternative index in interval-valued 2-tuple linguistic decision matrix $\widetilde{R}_k = (\widetilde{r}_{ij}^k)_{m\times n} = ([(r_{ij}^k, 0), (t_{ij}^k, 0)])_{m\times n}$ can be determined according to the following ways:

(i) A certain grade such as VH, which can be written as $[(s_5, 0), (s_5, 0)]$.

(ii) An interval such as $EL - M$, which means that the assessment of an alternative with respect to the criterion under consideration is between VL and M. This can be written as $[(s_0, 0), (s_3, 0)]$.

(iii) No judgment, which means the decision maker is not willing to or cannot provide an assessment for an alternative with respect to the criterion under consideration. In other words, the assessment by this decision maker could be anywhere between EL and EH, which can be expressed as $[(s_0, 0), (s_6, 0)]$.

Stage 3. Aggregate the interval 2-tuple linguistic values of group opinions.

Step 1. With different interval 2-tuple linguistic values for one criterion of each alternative, the order of values from different people can be determined adopting Definition 6.

Step 2. Aggregate the decision makers' opinions to construct collective interval 2-tuple linguistic decision matrices which are divided into $\widetilde{R}_P$ and $\widetilde{R}_E$ representing the opinion of the public group and expert group separately based on (10) and (11). That is to say, every alternative is expressed by two evaluation matrices in interval 2-tuple linguistic.

Stage 4. Select the best alternative by VIKOR method.

Step 1. Determine the 2-tuple linguistic positive ideal solution (PIS) (r_j^+, α_j^+) and the 2-tuple linguistic negative ideal solution (NIS) (r_j^-, α_j^-) of the collective interval 2-tuple linguistic decision matrices $(j = 1, 2, \dots, n)$:

$$\left(r_j^+, \alpha_j^+\right) = \begin{Bmatrix} \max\limits_i \left\{\left(t_{ij}, \varepsilon_{ij}\right)\right\}, \textit{for benefit criteria} \\ \min\limits_i \left\{\left(s_{ij}, \alpha_{ij}\right)\right\}, \textit{for cost criteria} \end{Bmatrix} \tag{13}$$

$$\left(r_j^-, \alpha_j^-\right) = \begin{Bmatrix} \min\limits_i \left\{\left(s_{ij}, \alpha_{ij}\right)\right\}, \textit{for benefit criteria} \\ \max\limits_i \left\{\left(t_{ij}, \varepsilon_{ij}\right)\right\}, \textit{for cost criteria} \end{Bmatrix} \tag{14}$$

Step 2. Compute the normalized 2-tuple linguistic distance $(\overline{d}_{ij}, \alpha_{ij})$ using the following equation based on (11),

$$\left(\overline{d}_{ij}, \alpha_{ij}\right) = \Delta\left(\frac{\Delta^{-1} d\left(\left(r_j^+, \alpha_j^+\right), \widetilde{r}_{ij}\right)}{\Delta^{-1} d\left(\left(r_j^+, \alpha_j^+\right), \left(r_j^-, \alpha_j^-\right)\right)}\right) \tag{15}$$

where $d((r_j^+, \alpha_j^+), \widetilde{r}_{ij}) = \Delta[(1/2)(|\Delta^{-1}(r_j^+, \alpha_j^+) - \Delta^{-1}(t_{ij}, \varepsilon_{ij})| + |\Delta^{-1}(r_j^+, \alpha_j^+) - \Delta^{-1}(s_{ij}, \alpha_{ij})|)]$ and $d((r_j^+, \alpha_j^+), (r_j^-, \alpha_j^-)) = \Delta|\Delta^{-1}(r_j^+, \alpha_j^+) - \Delta^{-1}(r_j^-, \alpha_j^-)|$, $i = 1, 2, \dots, m$, $j = 1, 2, \dots, n$.

Step 3. Compute the 2-tuples (S_i, α_i) and (R_i, α_i) for experts group and public group by the following equations:

$$\left(S_i, \alpha_i\right) = \Delta\left(\sum_{j=1}^{n} w_j \cdot \Delta^{-1}\left(\overline{d}_{ij}, \alpha_{ij}\right)\right) \tag{16}$$

$$\left(R_i, \alpha_i\right) = \Delta\left(\max_j\left(w_j \cdot \Delta^{-1}\left(\overline{d}_{ij}, \alpha_{ij}\right)\right)\right) \tag{17}$$

Step 4. With the value of (S_i^E, α_i^E) for experts group and (S_i^P, α_i^P) for public group, the collective 2-tuple (S_i^C, α_i^C) can be computed by the following equation:

$$\begin{aligned} &\left(S_i^C, \alpha_i^C\right) \\ &\quad = \Delta\left[\lambda \cdot \Delta^{-1}\left(S_i^E, \alpha_i^E\right) + (1-\lambda)\, \Delta^{-1}\left(S_i^P, \alpha_i^P\right)\right] \end{aligned} \tag{18}$$

where λ is introduced as a weight for evaluation committee assessments, $1-\lambda$ is the weight of the public assessments, and the value of λ is taken as 0.5 representing that the assessments of the public are as important as the assessments of evaluation committee, while it can take any value from 0 to 1.

And with the value of (R_i^E, α_i^E) for experts group and (R_i^P, α_i^P) for public group, the collective 2-tuple (R_i^C, α_i^C) can be computed by the following equation:

$$\begin{aligned} &\left(R_i^C, \alpha_i^C\right) \\ &\quad = \Delta\left[\lambda \cdot \Delta^{-1}\left(R_i^E, \alpha_i^E\right) + (1-\lambda) \cdot \Delta^{-1}\left(R_i^P, \alpha_i^P\right)\right] \end{aligned} \tag{19}$$

Step 5. Compute the 2-tuples (Q_i, α_i), $i = 1, 2, \dots, m$, using the following equation:

$$\begin{aligned} \left(Q_i, \alpha_i\right) = \Delta\Bigg(& \nu \frac{\Delta^{-1}\left(S_i^C, \alpha_i^C\right) - \Delta^{-1}\left(S^*, \alpha^*\right)}{\Delta^{-1}\left(S^-, \alpha^-\right) - \Delta^{-1}\left(S^*, \alpha^*\right)} \\ & + (1-\nu) \frac{\Delta^{-1}\left(R_i^C, \alpha_i^C\right) - \Delta^{-1}\left(R^*, \alpha^*\right)}{\Delta^{-1}\left(R^-, \alpha^-\right) - \Delta^{-1}\left(R^*, \alpha^*\right)} \Bigg) \end{aligned} \tag{20}$$

where $(S^*, \alpha^*) = \min(S_i^C, \alpha_i^C)$, $(S^-, \alpha^-) = \max_i(S_i^C, \alpha_i^C)$, $(R^*, \alpha^*) = \min_i(R_i^C, \alpha_i^C)$, $(R^-, \alpha^-) = \max_i(R_i^C, \alpha_i^C)$, and ν is introduced as a weight for the strategy of maximum group utility, whereas $1-\nu$ is the weight of the individual regret. The value of ν is usually taken as 0.5, while it can take any value from 0 to 1.

Step 6. Select the best alternative for WtE plant site checked by VIKOR shown in Section 4.

6. A Case Study

Based on the huge disposal demand of municipal solid waste, more and more WtE plants are under construction or in the urban planning. In order to grasp these opportunities, an environmental protection company called company X which has the ability to complete the WtE plant construction program is planning to expand its business in South China. In order to conduct the business, several experts and research analysts are invited to choose the areas to build WtE plants, which forms an evaluation committee. To avoid personal tendencies misleading the evaluation results, the members of the evaluation committee consist of people having different fields concerning the selection of potential sites, including an expert (DM_1) who had studied in garbage power generation for years, a government policy researcher (DM_2) proficient in policy analysis, and a senior project manager (DM_3) having related business background [56]. Thus, the evaluation result is ensured to meet the basic requirement with technical feasibility, policy compliance, and economic benefits during operation after the plant is built.

In phase I, 9 alternatives are figured out after a preliminary investigation to detailed policy terms comparison of provinces in the south of China. Soon afterwards 4 alternatives are removed due to technical limitation. So 5 alternatives are left involving Yangzhou (A_1), Xinyi (A_2), Xuzhou (A_3), Qingtian (A_4), and Haiyan (A_5) which seem to be suitable and should be taken into consideration as shown in Figure 3. To gain the optimal choice, the comparison between these five alternatives is made next and the evaluation criteria system is established as Table 1 after repeated discussion from evaluation committee. There is a point to mention that, during the process establishing the criteria system, correlation between decision factors, indexes, or subindexes is realized as little as possible both in the concept and in the connotation. The established criteria also met the requirement of comprehension and accuracy of the evaluation including quantitative criteria and qualitative criteria. And with further investigation, the quantitative

Table 2: Quantitative criteria value of alternatives.

Criteria	Yangzhou	Xinyi	Xuzhou	Qingtian	Haiyan
a_1 (CNY/kW)	3.92	3.54	3.78	3.49	3.56
a_2 (CNY/kW)	0.12	0.09	0.05	0.08	0.13
b_1 (km)	28	23	35	13	18
b_2 (kJ/kg)	5347	5528	5692	5471	5196
C_{13} (km)	4.1	5.6	6.2	4.5	3.5
C_{14} (km)	9.5	12.5	14	12	11.5
C_{15} (m)	170	260	100	320	180
C_{21} (CNY/m^2)	99	90	95	80	75
C_{23} (m)	1650	1867	2245	2174	2350
C_{31} (CNY/kWh)	0.65	0.65	0.65	0.65	0.65
C_{13} (km)	85	85	85	65	65
d_1 (m^2/a)	33820	34750	37640	31560	35460
d_2 (t/a)	73649	73890	74653	73158	73986
d_3 (t/a)	25840	22560	28630	22560	25890
e_3 (t/a)	61380	62690	64108	61350	62970

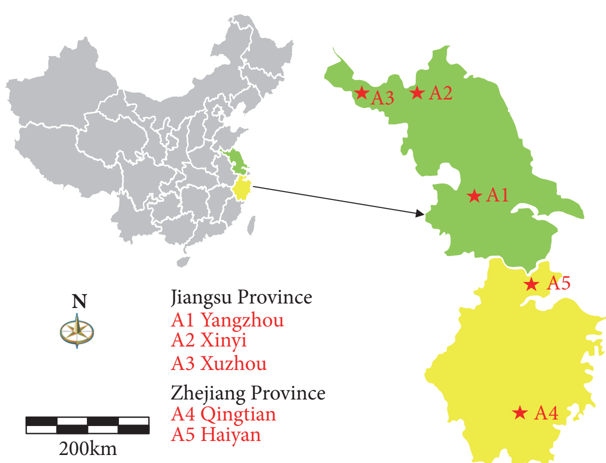

Figure 3: The geographical locations of alternatives.

criteria values of alternatives are found out shown in Table 2. For qualitative criteria, detailed documents are provided as judgments basis.

In phase II, with the cooperation of evaluation committee members, the weight of each decision factor, index, and subindex is gotten with the AHP method. In order to investigate the relative weighting of decision factors, indexes, and subindexes separately, 10 judgement matrices including 1 decision matrix, 6 index matrices, and 4 subindex matrices are built and all the consistency ratios (CRs) are less than 0.1 which means the level of inconsistency in the comparison matrices is acceptable. And it proved that the values of the weights are valid as shown in Table 3.

In phase III, the evaluation committee and public group are invited to employ the same linguistic term set to evaluate the alternatives with respect to the above selection criteria. The evaluation committee and public group are seen as two independent evaluation agencies until the determination phase in VIKOR method. With the assessments of evaluation committee, the processing steps are as follows.

Step 1. With 3 assessments provided with a set of 7 labels by evaluation committee in Table 4, convert the assessments information into interval-valued 2-tuple linguistic information.

Step 2. Make a sequence in order about every criterion by Definition 6.

Step 3. Aggregate the intervalued 2-tuple linguistic about every criteria of each alternative by (11). Let $\mu(x) = x^2$, $H_{\sigma(k)} = i/3$, $k = 1, 2, 3$, and then $\omega_k = (k/3)^2 - ((k-1)/3)^2$ and $\omega_1 = 1/9$, $\omega_2 = 3/9$, $\omega_3 = 5/9$. The aggregated result of evaluation committee is shown in Table 5.

Step 4. Based on the distinguishing of cost indicator and benefit indicator, the PIS and NIS of the collective interval 2-tuple linguistic matrix by evaluation committee are determined as Table 6.

Step 5. The normalized 2-tuple linguistic distances $(\overline{d}_{ij}, \alpha_{ij})$ are calculated by (15) and shown in Table 7.

Step 6. The 2-tuples (S_i^E, α_i^E), (R_i^E, α_i^E) and $(Q_i^{\,E}, \alpha_i^{\,E})$ $i = 1, 2, 3, 4, 5$ are computed by (16) and (17) and the results are shown in Table 8.

In phase IV, a questionnaire is designed to gain the assessments of public. In the questionnaire, a written list of questions is divided into 6 parts in view of 6 decision factors. Finally, a total of 200 questionnaires are collected and 152 questionnaires are complete and valid. Different from phase III, the weight of every public assessment is equal and $\omega_n = \overline{\omega} = 0.00658$, $n = 1, 2, 3, \ldots, 152$. The aggregated result of public assessments is shown as Table 9. Similar to the steps in phase III, the 2-tuples (S_i^P, α_i^P), (R_i^P, α_i^P) and $(Q_i^{\,P}, \alpha_i^{\,P})$

Table 3: The weights of the decision factors, indexes and sub-indexes.

$C_1(0.2106)$	$C_2(0.0873)$	$C_3(0.4532)$	$C_4(0.0559)$	$C_5(0.1258)$	$C_6(0.0672)$
$C_{11}[0.0536]$	$C_{21}[0.0727]$	$C_{31}[0.2937]$	$C_{41}[0.0348]$	$C_{51}[0.0815]$	$C_{61}[0.0391]$
$a_1(0.0483)$	$C_{22}[0.0145]$	$C_{32}[0.0554]$	$C_{42}[0.0077]$	$d_1(0.0244)$	$C_{62}[0.0074]$
$a_2(0.0054)$		$C_{33}[0.1042]$	$C_{43}[0.0134]$	$d_2(0.0489)$	$C_{63}[0.0208]$
$C_{12}[0.1092]$				$d_3(0.0081)$	
$b_1(0.0261)$				$C_{52}[0.0289]$	
$b_2(0.0680)$				$e_1(0.0032)$	
$b_3(0.0150)$				$e_2(0.0089)$	
$C_{13}[0.0125]$				$e_3(0.0168)$	
$C_{14}[0.0084]$				$C_{53}[0.0154]$	
$C_{15}[0.0270]$					

Table 4: Assessments by evaluation committee of A_1.

Criteria	DM_1	DM_2	DM_3
a_1	EH	H-VH	VH
a_2	H-VH	M-H	M
b_1	VH	M	M-H
b_2	L-M	L-M	VL
b_3	M-H	M	M
C_{13}	M	L	VL
C_{14}	L	VL	L
C_{15}	L	M	L
C_{21}	H	VH	EH
C_{23}	M	VL	VL
C_{31}	VH	VH	VH
C_{32}	VH	M-H	EH
C_{33}	H	VH	H
C_{41}	H	M	H
C_{42}	M	H	M
C_{43}	M-H	M	H
d_1	L-M	L	H-VH
d_2	M	M	VH
d_3	M	M	H-VH
e_1	EL-VL	VL	VL
e_2	VL	EL-VL	VL
e_3	L	L	H
C_{53}	L-M	L	M
C_{61}	M	VH	M
C_{62}	M-H	H	M
C_{63}	VL-L	M	L

$i = 1, 2, 3, 4, 5$ are computed and the results are shown in Table 10.

In phase V, collective 2-tuples (S_i^C, α_i^C), (R_i^C, α_i^C), and (Q_i^C, α_i^C) are calculated by (18) and (19) and the results are shown in Table 11. By ranking the alternatives in keeping with the 2-tuples (S_i^C, α_i^C), (R_i^C, α_i^C), and (Q_i^C, α_i^C), the ranking lists of the five alternatives are shown in Table 12. As we can see from Table 12, the ranking of the five alternatives is $A_3 \succ A_1 \succ A_2 \succ A_4 \succ A_5$ in accordance with the 2-tuples of (Q_i^C, α_i^C) in ascending order. Considering $DQ = 1/(5-1) = 0.25$, $\Delta^{-1}(Q_1^C, \alpha_1^C) - \Delta^{-1}(Q_3^C, \alpha_3^C) < DQ$, and $\Delta^{-1}(Q_2^C, \alpha_2^C) - \Delta^{-1}(Q_3^C, \alpha_3^C) \geq DQ$, both alternatives A_1 (Yangzhou) and A_3 (Xuzhou) are the suitable disposal sites for the considered application example. The order of the rest is Xinyi, Qingtian, and Haiyan.

Table 5: Aggregated result of evaluation committee assessments.

Criteria	A_1	A_2	A_3	A_4	A_5
a_1	Δ[4.556,5.111]	Δ[3.000,3.000]	Δ[4.000,4.111]	Δ[1.222,1.556]	Δ[2.000,2.556]
a_2	Δ[3.111,3.556]	Δ[2.444,2.444]	Δ[1.111,1.111]	Δ[2.444,2.444]	Δ[3.556,3.556]
b_1	Δ[3.222,3.556]	Δ[2.556,3.111]	Δ[4.556,4.556]	Δ[0.889,0.889]	Δ[1.556,1.556]
b_2	Δ[1.444,1.889]	Δ[2.556,2.667]	Δ[3.222,3.222]	Δ[1.667,2.556]	Δ[0.889,1.000]
b_3	Δ[3.000,3.111]	Δ[1.111,1.111]	Δ[2.333,2.333]	Δ[1.444,1.444]	Δ[3.222,3.222]
C_{13}	Δ[1.556,1.556]	Δ[3.000,3.111]	Δ[3.444,3.556]	Δ[2.111,2.111]	Δ[1.111,1.222]
C_{14}	Δ[1.444,1.444]	Δ[3.444,3.444]	Δ[4.444,4.444]	Δ[3.444,3.444]	Δ[2.444,3.111]
C_{15}	Δ[2.111,2.111]	Δ[3.222,4.111]	Δ[1.111,1.111]	Δ[4.222,4.222]	Δ[2.111,2.111]
C_{21}	Δ[4.556,4.556]	Δ[3.111,3.444]	Δ[2.222,3.222]	Δ[2.444,2.444]	Δ[1.889,1.889]
C_{23}	Δ[1.222,1.222]	Δ[1.556,1.556]	Δ[2.889,3.000]	Δ[2.556,2.556]	Δ[3.333,3.333]
C_{31}	Δ[5.000,5.000]	Δ[5.000,5.000]	Δ[5.000,5.000]	Δ[4.444,4.444]	Δ[4.111,4.111]
C_{32}	Δ[4.000,4.556]	Δ[4.444,4.444]	Δ[4.444,4.444]	Δ[4.556,4.556]	Δ[3.556,4.111]
C_{33}	Δ[4.111,4.111]	Δ[3.556,3.556]	Δ[3.556,4.111]	Δ[1.222,1.222]	Δ[1.222,1.222]
C_{41}	Δ[3.444,3.444]	Δ[2.444,2.556]	Δ[2.000,2.333]	Δ[2.444,2.444]	Δ[5.000,5.000]
C_{42}	Δ[3.111,3.111]	Δ[3.111,3.444]	Δ[2.444,2.444]	Δ[3.556,4.444]	Δ[1.111,1.444]
C_{43}	Δ[3.111,3.444]	Δ[4.444,4.444]	Δ[4.222,4.222]	Δ[2.556,2.556]	Δ[1.444,1.444]
d_1	Δ[2.222,2.667]	Δ[3.222,3.222]	Δ[5.111,5.111]	Δ[1.333,1.667]	Δ[3.556,3.556]
d_2	Δ[3.222,3.222]	Δ[2.667,3.111]	Δ[4.222,4.222]	Δ[2.222,2.333]	Δ[3.556,4.222]
d_3	Δ[3.111,3.222]	Δ[1.667,1.667]	Δ[4.444,4.444]	Δ[1.667,1.667]	Δ[3.111,3.222]
e_1	Δ[0.444,1.000]	Δ[1.111,1.111]	Δ[1.444,1.444]	Δ[1.111,1.111]	Δ[0.444,1.000]
e_2	Δ[0.444,1.000]	Δ[1.000,1.111]	Δ[0.444,0.556]	Δ[0.444,0.556]	Δ[1.000,1.000]
e_3	Δ[2.222,2.222]	Δ[3.444,3.556]	Δ[4.444,4.444]	Δ[2.222,2.222]	Δ[3.444,4.111]
C_{53}	Δ[2.111,2.444]	Δ[1.444,1.444]	Δ[1.889,1.889]	Δ[0.889,0.889]	Δ[1.556,2.111]
C_{61}	Δ[3.222,3.222]	Δ[2.444,3.000]	Δ[3.111,3.111]	Δ[2.111,2.111]	Δ[1.000,1.111]
C_{62}	Δ[3.111,3.444]	Δ[2.444,3.000]	Δ[4.111,4.111]	Δ[1.111,1.111]	Δ[3.000,3.000]
C_{63}	Δ[1.556,2.111]	Δ[2.889,3.444]	Δ[3.556,3.556]	Δ[3.000,3.111]	Δ[2.111,2.444]

7. Sensitivity Analysis

To figure out the influence on the decision making of WtE plant site selection with the public satisfaction, a sensitivity analysis by changing the weight character parameter λ of evaluation committee assessments is computed in the light of information in Tables 8 and 10. The values $\Delta^{-1}(Q_i^C, \alpha_i^C)$ for five alternatives' WtE sites under different λ values are presented in Figure 4. And the calculated result also shows that the 2-tuples (S_3^C, α_3^C) and (R_3^C, α_3^C) are always the minimum in five alternatives. In Figure 4, the value of λ is between 0 and 1 with a spacing of 0.1. In addition, the red line is $DQ = 0.25$. From Figure 4, we can find out following change characteristics of the $\Delta^{-1}(Q_i^C, \alpha_i^C)$.

(i) When $\lambda = 1$, the 2-tuples (Q_i^C, α_i^C) are the same as the 2-tuples (Q_i^E, α_i^E) which means that the collective evaluation result is determined by evaluation committee.

(ii) When $\lambda = 0$, the 2-tuples (Q_i^C, α_i^C) are the same as the 2-tuples (Q_i^P, α_i^P) which means that the collective evaluation result is decided by the public.

(iii) With the change of λ value, the value $\Delta^{-1}(Q_3^C, \alpha_3^C)$ is always 0 indicating A_3 is always the best choice for WtE site. On the contrary, the value $\Delta^{-1}(Q_5^C, \alpha_5^C)$ is always 1 meaning A_5 is not suitable for WtE site.

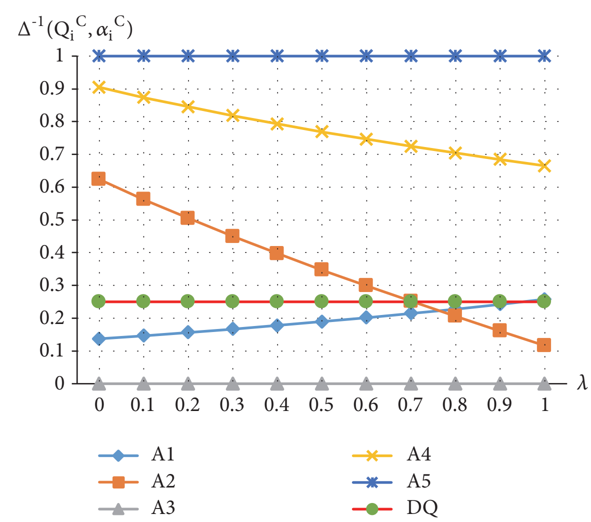

Figure 4: Values $\Delta^{-1}(Q_i^C, \alpha_i^C)$ for five alternatives under different λ values.

TABLE 6: The collective PIS and NIS by evaluation committee.

Criteria	(r_j^+, α_j^+)	(r_j^-, α_j^-)
a_1	$\Delta(1.222)$	$\Delta(5.111)$
a_2	$\Delta(1.111)$	$\Delta(3.556)$
b_1	$\Delta(0.889)$	$\Delta(4.556)$
b_2	$\Delta(3.222)$	$\Delta(0.889)$
b_3	$\Delta(1.111)$	$\Delta(3.222)$
C_{13}	$\Delta(1.111)$	$\Delta(3.556)$
C_{14}	$\Delta(1.444)$	$\Delta(4.444)$
C_{15}	$\Delta(1.111)$	$\Delta(4.222)$
C_{21}	$\Delta(1.889)$	$\Delta(4.556)$
C_{23}	$\Delta(3.333)$	$\Delta(1.222)$
C_{31}	$\Delta(5.000)$	$\Delta(4.111)$
C_{32}	$\Delta(4.556)$	$\Delta(3.556)$
C_{33}	$\Delta(4.111)$	$\Delta(1.222)$
C_{41}	$\Delta(5.000)$	$\Delta(2.000)$
C_{42}	$\Delta(4.444)$	$\Delta(1.111)$
C_{43}	$\Delta(4.444)$	$\Delta(1.444)$
d_1	$\Delta(5.111)$	$\Delta(1.333)$
d_2	$\Delta(4.222)$	$\Delta(2.222)$
d_3	$\Delta(4.444)$	$\Delta(1.667)$
e_1	$\Delta(0.444)$	$\Delta(1.444)$
e_2	$\Delta(0.444)$	$\Delta(1.111)$
e_3	$\Delta(4.444)$	$\Delta(2.222)$
C_{53}	$\Delta(0.889)$	$\Delta(2.444)$
C_{61}	$\Delta(3.222)$	$\Delta(1.000)$
C_{62}	$\Delta(4.111)$	$\Delta(1.111)$
C_{63}	$\Delta(3.556)$	$\Delta(1.556)$

(iv) With the line $DQ = 0.25$, it is easy to know that $\Delta^{-1}(Q_1{}^C, \alpha_1{}^C) < 0.25$ when λ is no more than 0.9 and $\Delta^{-1}(Q_2{}^C, \alpha_2{}^C) < 0.25$ when λ is no less than 0.8.

Furthermore, alternative A_3 is always the best ranked by the minimum value by S and R with different λ values. Thus, alternative A_i would be suitable site for WtE plant when $\Delta^{-1}(Q_i{}^C, \alpha_i{}^C) < 0.25$. Table 13 shows the ranking of alternatives and suitable sites with different λ values. As we can see from Figure 4 and Table 13, A_3 has got the unanimous support of evaluation committee and the public. But when it comes to the second suitable site selection, the evaluation committee has a disagreement with the public. Thereinto, evaluation committee think A_2 is more appropriate than A_3 while the public is in favor of A_1. Based on the above analysis, the result of WtE plant site selection can be more serviceable with the comprehensive evaluation of the public and experts from multiple alternatives.

8. Conclusion

For a long time, the construction of waste incineration power plants in China is not only constrained by technical conditions, but faced with the hindrance of NIMBY conflicts. So it has become an inevitable problem that by how to choose WtE sites government can satisfy the public. In this study, three theoretical methods including AHP method, interval 2-tuple linguistic sets, and VIKOR method are combined to realize the description and calculation of the evaluations from different groups. Then, the use of an empirical case demonstrates the applicability and effectivity of the proposed approach. In the case, policy factor is the most important decision factor shown in Table 1 which is consistent with the industry situation in south China. And the final result shows that A3 (Xinyi) is the optimal WtE site location for the company to launch the construction project.

In spite of some contributions that have been made, there are still some limitations in this study. Firstly, the process of questionnaire collection will increase the cost of time and capital in order to get the objective evaluation result from the public. And the increase of the project evaluation cost may not be accepted by some investment companies. Secondly, the proposed method could not find the optimal project portfolio when the contradiction exists between different site alternatives and the investment company has the willingness to choose multiple projects. In future research, we are going to adopt some behavioral psychology theories and simulation theory to give the assessments of groups with different backgrounds. Then the repetitive cost problem

Table 7: Normalized 2-tuple linguistic distances of evaluation committee assessments.

Criteria	A_1	A_2	A_3	A_4	A_5
a_1	Δ(0.0003)	Δ(0.0217)	Δ(0.0163)	Δ(0.0323)	Δ(0.0421)
a_2	Δ(0.0008)	Δ(0.0014)	Δ(0.0005)	Δ(0.0038)	Δ(0.0043)
b_1	Δ(0.0095)	Δ(0.0077)	Δ(0.0031)	Δ(0.0157)	Δ(0.0257)
b_2	Δ(0.0234)	Δ(0.0341)	Δ(0.0048)	Δ(0.0579)	Δ(0.0605)
b_3	Δ(0.0030)	Δ(0.0065)	Δ(0.0009)	Δ(0.0113)	Δ(0.0129)
C_{13}	Δ(0.0023)	Δ(0.0018)	Δ(0.0020)	Δ(0.0046)	Δ(0.0110)
C_{14}	Δ(0.0015)	Δ(0.0025)	Δ(0.0028)	Δ(0.0016)	Δ(0.0070)
C_{15}	Δ(0.0055)	Δ(0.0151)	Δ(0.0025)	Δ(0.0210)	Δ(0.0212)
C_{21}	Δ(0.0166)	Δ(0.0382)	Δ(0.0007)	Δ(0.0468)	Δ(0.0672)
C_{23}	Δ(0.0014)	Δ(0.0059)	Δ(0.0027)	Δ(0.0094)	Δ(0.0097)
C_{31}	Δ(0.0913)	Δ(0.1874)	Δ(0.0636)	Δ(0.2355)	Δ(0.2405)
C_{32}	Δ(0.0260)	Δ(0.0265)	Δ(0.0048)	Δ(0.0280)	Δ(0.0445)
C_{33}	Δ(0.0123)	Δ(0.0445)	Δ(0.0110)	Δ(0.0695)	Δ(0.0854)
C_{41}	Δ(0.0119)	Δ(0.0195)	Δ(0.0062)	Δ(0.0229)	Δ(0.0281)
C_{42}	Δ(0.0026)	Δ(0.0041)	Δ(0.0007)	Δ(0.0076)	Δ(0.0077)
C_{43}	Δ(0.0017)	Δ(0.0062)	Δ(0.0034)	Δ(0.0107)	Δ(0.0102)
d_1	Δ(0.0054)	Δ(0.0135)	Δ(0.0035)	Δ(0.0143)	Δ(0.0188)
d_2	Δ(0.0108)	Δ(0.0230)	Δ(0.0098)	Δ(0.0316)	Δ(0.0207)
d_3	Δ(0.0026)	Δ(0.0019)	Δ(0.0078)	Δ(0.0031)	Δ(0.0027)
e_1	Δ(0.0003)	Δ(0.0011)	Δ(0.0023)	Δ(0.0019)	Δ(0.0023)
e_2	Δ(0.0016)	Δ(0.0057)	Δ(0.0025)	Δ(0.0076)	Δ(0.0067)
e_3	Δ(0.0122)	Δ(0.0058)	Δ(0.0100)	Δ(0.0115)	Δ(0.0101)
C_{53}	Δ(0.0029)	Δ(0.0080)	Δ(0.0089)	Δ(0.0113)	Δ(0.0140)
C_{61}	Δ(0.0056)	Δ(0.0295)	Δ(0.0101)	Δ(0.0280)	Δ(0.0318)
C_{62}	Δ(0.0041)	Δ(0.0048)	Δ(0.0011)	Δ(0.0061)	Δ(0.0064)
C_{63}	Δ(0.0018)	Δ(0.0084)	Δ(0.0024)	Δ(0.0117)	Δ(0.0142)

Table 8: The 2-tuples (S_i^E, α_i^E), (R_i^E, α_i^E) and (Q_i^E, α_i^E) by evaluation committee.

	A_1	A_2	A_3	A_4	A_5
(S_i^E, α_i^E)	Δ(0.3672)	Δ(0.2945)	Δ(0.1863)	Δ(0.5556)	Δ(0.6746)
(R_i^E, α_i^E)	Δ(0.0727)	Δ(0.0379)	Δ(0.0352)	Δ(0.1835)	Δ(0.2937)
(Q_i^E, α_i^E)	Δ(0.2579)	Δ(0.1161)	Δ(0.0000)	Δ(0.6652)	Δ(1.0000)

in program evaluation would be solved to some extent. In addition, more evaluation methodologies will be studied contraposing different choice scenarios, such as ELECTRE method to choose optimal project portfolio from given alternatives.

Data Availability

The data in this study is all obtained by personal investigation and expert consultant. And it is shown in the manuscript and the supplementary materials.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This paper is supported by the Fundamental Research Funds for the Central Universities (NO. 2018ZD14) and the 2017 Special Project of Cultivation and Development of Innovation Base (NO. Z171100002217024).

Supplementary Materials

There are two tables in the supplementary material which belong to the details of the case study in Section 6. In the table "data of AHP method," the data source of the AHP computing result in Table 3 is shown. Thereinto, the first layer is corresponding to the evaluation of decision factors' weights. The second layer contains the data source of indexes according to different decision factors. And the

Table 9: Aggregated result of public assessments.

Criteria	A_1	A_2	A_3	A_4	A_5
a_1	Δ[1.168,1.228]	Δ[2.211,4.239]	Δ[2.348,3.079]	Δ[3.578,4.892]	Δ[4.582,5.746]
a_2	Δ[0.626,1.292]	Δ[1.296,1.880]	Δ[0.039,1.240]	Δ[3.919,4.592]	Δ[3.697,5.961]
b_1	Δ[1.542,2.306]	Δ[1.186,1.972]	Δ[0.145,1.314]	Δ[2.498,3.684]	Δ[4.876,5.039]
b_2	Δ[3.501,4.036]	Δ[2.536,3.522]	Δ[4.728,5.386]	Δ[1.087,1.691]	Δ[0.687,1.722]
b_3	Δ[2.303,2.730]	Δ[3.040,3.745]	Δ[1.752,2.230]	Δ[4.073,5.116]	Δ[4.483,5.531]
C_{13}	Δ[0.804,1.872]	Δ[1.046,1.364]	Δ[0.733,1.753]	Δ[1.684,2.150]	Δ[3.191,3.946]
C_{14}	Δ[1.948,2.497]	Δ[2.307,2.988]	Δ[2.126,3.372]	Δ[1.631,2.934]	Δ[3.855,4.963]
C_{15}	Δ[1.150,2.300]	Δ[3.094,4.104]	Δ[0.653,1.642]	Δ[4.346,5.159]	Δ[3.676,5.939]
C_{21}	Δ[1.578,2.503]	Δ[3.262,3.452]	Δ[1.029,1.111]	Δ[3.362,4.401]	Δ[4.795,5.465]
C_{23}	Δ[4.311,5.053]	Δ[3.261,3.788]	Δ[3.850,4.871]	Δ[1.826,3.411]	Δ[1.273,3.785]
C_{31}	Δ[2.612,3.297]	Δ[1.831,2.330]	Δ[2.627,3.785]	Δ[1.346,1.939]	Δ[1.113,2.081]
C_{32}	Δ[2.524,3.723]	Δ[2.786,3.375]	Δ[4.743,5.676]	Δ[2.259,3.607]	Δ[0.247,2.380]
C_{33}	Δ[4.383,5.703]	Δ[2.194,4.434]	Δ[4.954,5.275]	Δ[1.888,2.061]	Δ[0.111,2.126]
C_{41}	Δ[2.466,5.433]	Δ[1.475,3.862]	Δ[3.875,5.972]	Δ[0.723,3.442]	Δ[0.066,2.362]
C_{42}	Δ[3.306,3.345]	Δ[2.181,2.567]	Δ[4.168,5.000]	Δ[0.211,0.229]	Δ[0.142,0.158]
C_{43}	Δ[4.664,5.673]	Δ[2.690,4.471]	Δ[3.349,5.778]	Δ[1.971,2.024]	Δ[1.059,3.273]
d_1	Δ[4.176,5.205]	Δ[2.139,3.371]	Δ[4.327,5.97]	Δ[2.018,3.137]	Δ[0.150,2.828]
d_2	Δ[3.031,5.190]	Δ[1.944,3.865]	Δ[3.435,4.995]	Δ[0.324,3.773]	Δ[2.022,4.233]
d_3	Δ[3.893,5.664]	Δ[4.773,5.275]	Δ[2.819,3.065]	Δ[3.509,5.677]	Δ[4.045,5.394]
e_1	Δ[0.344,1.048]	Δ[1.045,2.366]	Δ[2.047,4.179]	Δ[2.617,2.720]	Δ[2.728,3.529]
e_2	Δ[0.643,1.512]	Δ[2.144,3.275]	Δ[0.415,2.431]	Δ[2.958,4.006]	Δ[2.339,3.887]
e_3	Δ[2.075,2.411]	Δ[2.341,4.363]	Δ[1.441,3.815]	Δ[2.211,2.526]	Δ[2.027,3.194]
C_{53}	Δ[1.266,2.743]	Δ[2.582,3.976]	Δ[2.987,4.057]	Δ[4.021,4.205]	Δ[4.460,5.148]
C_{61}	Δ[4.387,5.479]	Δ[2.419,2.768]	Δ[3.987,5.002]	Δ[1.665,3.827]	Δ[2.199,2.540]
C_{62}	Δ[2.883,3.594]	Δ[2.710,3.163]	Δ[4.072,5.060]	Δ[1.795,2.940]	Δ[1.906,2.543]
C_{63}	Δ[5.337,5.526]	Δ[3.550,3.964]	Δ[4.686,5.884]	Δ[1.998,3.866]	Δ[0.642,3.936]

Table 10: The 2-tuples (S_i^P, α_i^P), (R_i^P, α_i^P) and (Q_i^P, α_i^P) of public assessments.

	A_1	A_2	A_3	A_4	A_5
(S_i^P, α_i^P)	Δ(0.2577)	Δ(0.5248)	Δ(0.1843)	Δ(0.7054)	Δ(0.8060)
(R_i^P, α_i^P)	Δ(0.0913)	Δ(0.1874)	Δ(0.0636)	Δ(0.2355)	Δ(0.2405)
(Q_i^P, α_i^P)	Δ(0.1372)	Δ(0.6236)	Δ(0.0000)	Δ(0.9049)	Δ(1.0000)

Table 11: The 2-tuples (S_i^C, α_i^C), (R_i^C, α_i^C) and (Q_i^C, α_i^C) of five alternatives.

	A_1	A_2	A_3	A_4	A_5
(S_i^C, α_i^C)	Δ(0.3124)	Δ(0.4097)	Δ(0.1853)	Δ(0.6305)	Δ(0.7403)
(R_i^C, α_i^C)	Δ(0.0820)	Δ(0.1126)	Δ(0.0494)	Δ(0.2095)	Δ(0.2671)
(Q_i^C, α_i^C)	Δ(0.1894)	Δ(0.3473)	Δ(0.0000)	Δ(0.7689)	Δ(1.0000)

Table 12: The rankings of the alternatives by (S_i^C, α_i^C), (R_i^C, α_i^C) and (Q_i^C, α_i^C).

	A_1	A_2	A_3	A_4	A_5
By (S_i^C, α_i^C)	2	3	1	4	5
By (R_i^C, α_i^C)	2	3	1	4	5
By (Q_i^C, α_i^C)	2	3	1	4	5

Table 13: Ranking of alternatives with different λ values.

λ	Ranking of alternative	Suitable alternatives
[0.0, 0.7]	$A_3 > A_1 > A_2 > A_4 > A_5$	A_3 A_1
[0.8, 0.9]	$A_3 > A_2 > A_1 > A_4 > A_5$	A_3 A_1 A_2
1	$A_3 > A_2 > A_1 > A_4 > A_5$	A_3 A_2

third layer illustrates the evaluation data of subindexes with homologous indexes. The table "data of evaluation committee assessments" is the complete data of Table 4. In this table, the evaluation assessments in interval linguistic terms are divided into three tables by DM_1, DM_2, and DM_3 representing the opinion of every member in evaluation committee. *(Supplementary Materials)*

References

[1] F. A. M. Lino and K. A. R. Ismail, "Incineration and recycling for MSW treatment: Case study of Campinas, Brazil," *Sustainable Cities and Society*, vol. 35, pp. 752–757, 2017.

[2] S. Tan, H. Hashim, C. Lee, M. R. Taib, and J. Yan, "Economical and environmental impact of waste-to-energy (Wte) alternatives for waste incineration, landfill and anaerobic digestion," in *Proceedings of the International Conference on Applied Energy*, pp. 704–708, 2014.

[3] Q. Song, Z. Wang, and J. Li, "Exploring residents' attitudes and willingness to pay for solid waste management in Macau," *Environmental Science and Pollution Research*, vol. 23, no. 16, pp. 16456–16462, 2016.

[4] M. Hupponen, K. Grönman, and M. Horttanainen, "How should greenhouse gas emissions be taken into account in the decision making of municipal solid waste management procurements? A case study of the South Karelia region, Finland," *Waste Management*, vol. 42, pp. 196–207, 2015.

[5] K. O. Demirarslan, M. K. Korucu, and A. Karademir, "Did we choose the best one? A new site selection approach based on exposure and uptake potential for waste incineration," *Waste Management & Research*, vol. 34, no. 8, pp. 755–763, 2016.

[6] M. Abedi, R. Mohammadi, G.-H. Norouzi, and M. S. M. Mohammadi, "A comprehensive VIKOR method for integration of various exploratory data in mineral potential mapping," *Arabian Journal of Geosciences*, vol. 9, no. 6, 2016.

[7] H.-C. Liu, J.-X. You, X.-J. Fan, and Y.-Z. Chen, "Site selection in waste management by the VIKOR method using linguistic assessment," *Applied Soft Computing*, vol. 21, pp. 453–461, 2014.

[8] X. Ren, Y. Che, K. Yang, and Y. Tao, "Risk perception and public acceptance toward a highly protested Waste-to-Energy facility," *Waste Management*, vol. 48, pp. 528–539, 2016.

[9] R. W. Saaty, "The analytic hierarchy process-what it is and how it is used," *Applied Mathematical Modelling: Simulation and Computation for Engineering and Environmental Systems*, vol. 9, no. 3-5, pp. 161–176, 1987.

[10] M. Hoseinpour, H. Sadrnia, M. Tabasizadeh, and B. Ghobadian, "Evaluation of the effect of gasoline fumigation on performance and emission characteristics of a diesel engine fueled with B20 using an experimental investigation and TOPSIS method," *Fuel*, vol. 223, pp. 277–285, 2018.

[11] X. Yu, S. Zhang, X. Liao, and X. Qi, "ELECTRE methods in prioritized MCDM environment," *Information Sciences*, vol. 424, pp. 301–316, 2018.

[12] A. T. d. A. Filho, T. R. Clemente, D. C. Morais, and A. T. de Almeida, "Preference modeling experiments with surrogate weighting procedures for the PROMETHEE method," *European Journal of Operational Research*, vol. 264, no. 2, pp. 453–461, 2018.

[13] M. Kumar and C. Samuel, "Selection of best renewable energy source by using VIKOR method," *Technology and Economics of Smart Grids and Sustainable Energy*, vol. 2, no. 1, 2017.

[14] J. Tan, K. Y. Low, N. M. Sulaiman, R. R. Tan, and M. A. Promentilla, "Fuzzy analytic hierarchy process (FAHP) for multi-criteria selection of microalgae harvesting and drying processes," in *Pres15: Process Integration, Modelling and Optimisation for Energy Saving and Pollution Reduction*, pp. 829–834, 2016.

[15] H. C. Liao, L. Y. Yang, and Z. S. Xu, "Two new approaches based on ELECTRE II to solve the multiple criteria decision making problems with hesitant fuzzy linguistic term sets," *Applied Soft Computing*, vol. 63, pp. 223–234, 2018.

[16] D. A. G. Chavira, J. C. L. Lopez, J. J. S. Noriega, O. A. Valenzuela, and P. A. A. Carrillo, "A credit ranking model for a parafinancial company based on the ELECTRE-III method and a multiobjective evolutionary algorithm," *Applied Soft Computing*, vol. 60, pp. 190–201, 2017.

[17] B. Sennaroglu and G. V. Celebi, "A military airport location selection by AHP integrated PROMETHEE and VIKOR methods," *Transportation Research Part D: Transport and Environment*, vol. 59, pp. 160–173, 2018.

[18] Y. Wu, J. Zhang, J. Yuan, S. Geng, and H. Zhang, "Study of decision framework of offshore wind power station site selection based on ELECTRE-III under intuitionistic fuzzy environment: A case of China," *Energy Conversion and Management*, vol. 113, pp. 66–81, 2016.

[19] H.-C. Liu, J. Wu, and P. Li, "Assessment of health-care waste disposal methods using a VIKOR-based fuzzy multi-criteria decision making method," *Waste Management*, vol. 33, no. 12, pp. 2744–2751, 2013.

[20] F. Zhou, X. Wang, and M. Goh, "Fuzzy extended VIKOR-based mobile robot selection model for hospital pharmacy," *International Journal Of Advanced Robotic Systems*, vol. 15, no. 4, 2018.

[21] H. Gupta, "Evaluating service quality of airline industry using hybrid best worst method and VIKOR," *Journal of Air Transport Management*, vol. 68, pp. 35–47, 2018.

[22] P. Shojaei, S. A. S. Haeri, and S. Mohammadi, "Airports evaluation and ranking model using Taguchi loss function, best-worst method and VIKOR technique," *Journal of Air Transport Management*, vol. 68, pp. 4–13, 2017.

[23] H.-C. Liu, J.-X. You, Y.-Z. Chen, and X.-J. Fan, "Site selection in municipal solid waste management with extended VIKOR method under fuzzy environment," *Environmental Earth Sciences*, vol. 72, no. 10, pp. 4179–4189, 2014.

[24] Y. Ju and A. Wang, "Extension of VIKOR method for multi-criteria group decision making problem with linguistic information," *Applied Mathematical Modelling: Simulation and Computation for Engineering and Environmental Systems*, vol. 37, no. 5, pp. 3112–3125, 2013.

[25] J.-Y. Dong, F.-F. Yuan, and S.-P. Wan, "Extended VIKOR method for multiple criteria decision-making with linguistic hesitant fuzzy information," *Computers & Industrial Engineering*, vol. 112, pp. 305–319, 2017.

[26] A. S. Ghadikolaei, M. Madhoushi, and M. Divsalar, "Extension of the VIKOR method for group decision making with extended hesitant fuzzy linguistic information," *Neural Computing and Applications*, pp. 1–14, 2017.

[27] S.-P. Wan, Q.-Y. Wang, and J.-Y. Dong, "The extended VIKOR method for multi-attribute group decision making with triangular intuitionistic fuzzy numbers," *Knowledge-Based Systems*, vol. 52, pp. 65–77, 2013.

[28] C. Rao, X. Xiao, M. Xie, M. Goh, and J. Zheng, "Low carbon supplier selection under multi-source and multi-attribute procurement," *Journal of Intelligent & Fuzzy Systems: Applications in Engineering and Technology*, vol. 32, no. 6, pp. 4009–4022, 2017.

[29] H. C. Liu, L. Liu, and J. Wu, "Material selection using an interval 2-tuple linguistic VIKOR method considering subjective and objective weights," *Materials and Corrosion*, vol. 52, pp. 158–167, 2013.

[30] X.-Y. You, J.-X. You, H.-C. Liu, and L. Zhen, "Group multi-criteria supplier selection using an extended VIKOR method with interval 2-tuple linguistic information," *Expert Systems with Applications*, vol. 42, no. 4, pp. 1906–1916, 2015.

[31] M. Tavana, D. Di Caprio, and F. J. Santos-Arteaga, "An extended stochastic VIKOR model with decision maker's attitude towards risk," *Information Sciences*, vol. 432, pp. 301–318, 2018.

[32] M. Aghajani Mir, P. T. Ghazvinei, N. M. N. Sulaiman et al., "Application of TOPSIS and VIKOR improved versions in a multi criteria decision analysis to develop an optimized municipal solid waste management model," *Journal of Environmental Management*, vol. 166, pp. 109–115, 2016.

[33] B. Debbarma, P. Chakraborti, P. K. Bose, M. Deb, and R. Banerjee, "Exploration of PROMETHEE II and VIKOR methodology in a MCDM approach for ascertaining the optimal performance-emission trade-off vantage in a hydrogen-biohol dual fuel endeavour," *Fuel*, vol. 210, pp. 922–935, 2017.

[34] L. Baccour, "Amended fused TOPSIS-VIKOR for classification (ATOVIC) applied to some UCI data sets," *Expert Systems with Applications*, vol. 99, pp. 115–125, 2018.

[35] H. Hashemi, S. Mousavi, E. Zavadskas, A. Chalekaee, and Z. Turskis, "A new group decision model based on grey-intuitionistic fuzzy-ELECTRE and VIKOR for contractor assessment problem," *Sustainability*, vol. 10, no. 5, p. 1635, 2018.

[36] M. Caniato, M. Vaccari, C. Visvanathan, and C. Zurbrügg, "Using social network and stakeholder analysis to help evaluate infectious waste management: A step towards a holistic assessment," *Waste Management*, vol. 34, no. 5, pp. 938–951, 2014.

[37] T. O. Somorin, S. Adesola, and A. Kolawole, "State-level assessment of the waste-to-energy potential (via incineration) of municipal solid wastes in Nigeria," *Journal of Cleaner Production*, vol. 164, pp. 804–815, 2017.

[38] J. M. Fernández-González, A. L. Grindlay, F. Serrano-Bernardo, M. I. Rodríguez-Rojas, and M. Zamorano, "Economic and environmental review of Waste-to-Energy systems for municipal solid waste management in medium and small municipalities," *Waste Management*, vol. 67, pp. 360–374, 2017.

[39] Y. Wu, K. Chen, B. Zeng, M. Yang, and S. Geng, "Cloud-based decision framework for waste-to-energy plant site selection—a case study from China," *Waste Management*, vol. 48, pp. 593–603, 2016.

[40] M. M.-U. Khan, S. Jain, M. Vaezi, and A. Kumar, "Development of a decision model for the techno-economic assessment of municipal solid waste utilization pathways," *Waste Management*, vol. 48, pp. 548–564, 2016.

[41] C. Sun, X. Meng, and S. Peng, "Effects of waste-to-energy plants on china's urbanization: Evidence from a hedonic price analysis in shenzhen," *Sustainability*, vol. 9, no. 3, pp. 1–18, 2017.

[42] L. Zheng, J. Song, C. Li et al., "Preferential policies promote municipal solid waste (MSW) to energy in China: Current status and prospects," *Renewable & Sustainable Energy Reviews*, vol. 36, pp. 135–148, 2014.

[43] J. Malinauskaite, H. Jouhara, D. Czajczyńska et al., "Municipal solid waste management and waste-to-energy in the context of a circular economy and energy recycling in Europe," *Energy*, vol. 141, pp. 2013–2044, 2017.

[44] C. Aracil, P. Haro, J. Giuntoli, and P. Ollero, "Proving the climate benefit in the production of biofuels from municipal solid waste refuse in Europe," *Journal of Cleaner Production*, vol. 142, pp. 2887–2900, 2017.

[45] S. Kimbrough, D. A. Vallero, R. C. Shores, and W. Mitchell, "Enhanced, multi criteria based site selection to measure mobile source toxic air pollutants," *Transportation Research Part D: Transport and Environment*, vol. 16, no. 8, pp. 586–590, 2011.

[46] K. Hadjibiros, D. Dermatas, and C. S. Laspidou, "Municipal solid waste management and landfill site selection in greece: irrationality versus efficiency," *Global NEST Journal*, vol. 13, no. 2, pp. 150–161, 2011.

[47] X. Li, M. Wang, W. Chen, and H. Uwizeyimana, "Ecological risk assessment of polymetallic sites using weight of evidence approach," *Ecotoxicology and Environmental Safety*, vol. 154, pp. 255–262, 2018.

[48] M. J. Walker, "Worth the effort? NIMBY public comments offer little value added," *Public Administration Review*, vol. 74, no. 5, p. 629, 2014.

[49] D. Pitt, "Renewable energy and the public: from nimby to participation," *Journal of Planning Education and Research*, vol. 32, no. 2, pp. 247–249, 2012.

[50] I. Arbulu, J. Lozano, and J. Rey-Maquieira, "The challenges of tourism to waste-to-energy public-private partnerships," *Renewable & Sustainable Energy Reviews*, vol. 72, pp. 916–921, 2017.

[51] F. Herrera and L. Martínez, "A 2-tuple fuzzy linguistic representation model for computing with words," *IEEE Transactions on Fuzzy Systems*, vol. 8, no. 6, pp. 746–752, 2000.

[52] W.-S. Tai and C.-T. Chen, "A new evaluation model for intellectual capital based on computing with linguistic variable," *Expert Systems with Applications*, vol. 36, no. 2, pp. 3483–3488, 2009.

[53] H. Zhang, "Some interval-valued 2-tuple linguistic aggregation operators and application in multiattribute group decision making," *Applied Mathematical Modelling*, vol. 37, no. 6, pp. 4269–4282, 2013.

[54] H. Zhang, "The multiattribute group decision making method based on aggregation operators with interval-valued 2-tuple linguistic information," *Mathematical and Computer Modelling*, vol. 56, no. 1-2, pp. 27–35, 2012.

[55] P. Wang, X. Xu, J. Wang, and C. Cai, "Interval-valued intuitionistic linguistic multi-criteria group decision-making method based on the interval 2-tuple linguistic information," *Journal Of Intelligent & Fuzzy Systems*, vol. 33, no. 2, pp. 985–994, 2017.

[56] A. Soltani, R. Sadiq, and K. Hewage, "Selecting sustainable waste-to-energy technologies for municipal solid waste treatment: A game theory approach for group decision-making," *Journal of Cleaner Production*, vol. 113, pp. 388–399, 2016.