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Site selection in waste management by the VIKOR method using linguistic assessment

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Site selection is an important issue in municipal solid waste (MSW) management. Selection of the appropriate solid waste site is an extensive evaluation process that requires consideration of multiple alternative solutions and evaluation criteria. In reality, it is easier for decision makers to express their judgments on the alternatives by using linguistic terms, and there usually exists uncertain and incomplete assessment information. Moreover, decision makers may have different risk attitudes in the siting process because of their different backgrounds and personalities. Therefore, an attitudinal-based interval 2-tuple linguistic VIKOR (ITL-VIKOR) method is proposed in this paper to select the best disposal site for MSW. The feasibility and practicability of the proposed method are further demonstrated through an example of refuse-derived fuel (RDF) combustion plant location. Results show that the new approach is more suitable and effective to handle the MSW site selection problems by considering the decision maker's attitudinal character and incorporating the uncertain and incomplete assessment information.

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UNCORRECTED PROOF

1. Introduction

Municipal solid waste (MSW) is the stream of solid waste generated by households, commercial establishments, industries and institutions, which consists of everyday items such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint and batteries [1]. The management of MSW is increasingly becoming a challenging task for the municipal authorities due to increasing waste quantities, changing waste composition, decreasing land availability for waste disposal sites and increasing awareness about the environmental risk associated with the waste management facilities [2]. The MSW management system can be thought to be a cycle with many closely related stages, which begins with the production of goods and continues with generation, storage, sweeping, collection and final disposal of waste [3]. Poor waste management systems coupled with hot climatic conditions result in increasing environmental problems with significant local as well as global dimensions [4]. Therefore, effective MSW management methods are desired to be developed, by which decision makers and waste management planners can deal with the increase in complexity, uncertainty, multi-objectivity, and subjectivity associated with the MSW management problem. In this paper, we focus on the final stage of the life cycle of MSW, i.e., the waste disposal.

MSW disposal sites have been the focus of special attention because they are a significant source of soil, water and air contamination. Selection of the appropriate solid waste facilities constitutes one of the primary issues of municipal solid waste disposal. Optimized siting decisions have gained considerable importance in order to ensure minimum damage to the various environmental sub-components as well as reduce the stigma associated with the residents living in its vicinity, thereby enhancing the overall sustainability associated with the MSW life cycle [4]. In the past decades, a number of mathematical analysis methods were proposed for supporting solid waste site selection problems. For example, Şener et al. [5] combined analytical hierarchy process (AHP) and geographic information system (GIS) to determine the landfill site for the Lake Beyşehir catchment area (Konya, Turkey). Sumathi et al. [4] used multi-criteria decision analysis and GIS for optimized siting of municipal solid waste landfill. Wang et al. [6] proposed the use of GIS based on AHP to select sites suitable for disposal of solid wastes. Other methods of integrating GIS with multi-criteria decision making (MCDM) for waste disposal site selection include [7–13]. In [14], the analytic network process (ANP) was applied to select the best location for the construction

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of a MSW plant in the metropolitan area of Valencia (Spain). On the other hand, some fuzzy methods have been developed to deal with the vagueness and ambiguity in the site selection process. For instance, Ekmekçioğlu et al. [15] presented an approach based on the use of fuzzy AHP-based fuzzy technique for order preference by similarity to an ideal solution (TOPSIS) methodology for the selection of appropriate disposal method and site for municipal solid waste. Önüt and Soner [16] proposed a combined AHP and fuzzy TOPSIS methodology for locating and selecting candidate areas in the transshipment site selection process of the solid wastes. Chang et al. [17] suggested an integrated approach of GIS and fuzzy AHP to construct a spatial decision support system (SDSS) for the selection of landfill sites. Akbari et al. [18] also integrated GIS and fuzzy AHP to solve the landfill site selection problem and to develop a ranking of the potential landfill areas based on a variety of criteria. In Ref. [19], a fuzzy MCDM approach was applied to solve the landfill selection problem in Regina of Saskatchewan Canada. The techniques that were used for the analysis of solid waste management systems include simple weighted addition (SWA) method, weighted product (WP) method, TOPSIS, cooperative game theory, and ELECTRE.

The above literature review demonstrates that the majority of researchers concentrated on site selection methods applying linguistic value by using fuzzy logic to handle the uncertainty in real situations. They usually deal with linguistic terms by using the extension principle [20] and the symbolic method [21]. As a result, an approximation process must be developed to express the results in the initial expression domain, since the computation results usually do not exactly match any of the initial linguistic terms. This produces a loss of information and hence a lack of precision in the final results [22–24]. In addition, decision makers are often unsure of their preferences during the site selection process because of time pressure, lack of experience and data. It is easier for a decision maker to describe a value for an alternative by using linguistic terms [16]. They often demonstrate different evaluations or opinions and produce different types of assessment information for a certain alternative concerning a given criterion, some of which may be precise or imprecise, certain or uncertain, and complete or incomplete. These different types of information are very hard to incorporate into the site selection by using the traditional models and fuzzy logic based methods. Whereas, the interval 2-tuple linguistic representation model [25–27] overcomes the above limitations. The advantages of this approach are that decision makers can express their preferences by the use of linguistic term sets with different granularity of uncertainty and their judgments can be expressed with an interval 2-tuple from the predefined linguistic term set. Therefore, the approach based on the interval 2-tuple linguistic variables is more flexible and precise to deal with linguistic terms in solving site selection problems in MSW management.

In other way, the evaluation of a new waste disposal site is a difficult and complicated process and it requires taking into consideration many parameters (or criteria) such as distance to residential area, distance from the main roads, investment costs, climate, availability of solid waste, land slope, and so on [16]. In order to select the best disposal location of the solid wastes to be collected it is necessary to make balance among these tangible and intangible factors some of which may conflict and compete. Moreover, there may be several decision makers take part in the evaluation of alternatives together during the selection and the placement of waste disposal facilities. For these reasons, waste facility selection can be viewed as a group MCDM (GMCDM) problem and GMCDM methods have been found to be a useful approach to solve this kind of problem. The VIKOR (VIsekriterijumska optimizacija i KOmpromisno Resenje) method, a very useful technique for GMCDM, was first developed by Opricovic [28] to solve a discrete decision problem with noncommensurable and conflicting criteria. This method focuses on ranking and selecting from a set of alternatives, and determines compromise solutions for a problem with conflicting criteria, which can help the decision makers to reach a final decision [29,30]. The compromise solution is a feasible solution, which is the closest to the ideal, and a compromise means an agreement established by mutual concessions. The main advantages of the VIKOR method are that it introduces the multi-criteria ranking index based on the particular measure of "closeness" to the ideal solution [31], and the obtained compromise solution provides a maximum group utility for the "majority" and a minimum individual regret for the "opponent" [29]. Due to its characteristics and capabilities, the VIKOR method has been widely studied and applied in group decision making problems in recent years [32–40].

The background introduced above shows that it may be inappropriate to use fuzzy methods for evaluation and selection of waste disposal sites because of the loss of information in the linguistic information processing. Moreover, decision makers tend to use different linguistic term sets to express their judgments on the subjective criteria, and there usually exist uncertain and incomplete assessments. Therefore, the aim of this study is to present a new GMCDM method with interval 2-tuple linguistic information to solve the site selection problem under uncertain and incomplete information environment. The method is an extended VIKOR for group decision making with interval 2-tuple linguistic variables. It can overcome both the drawbacks of the crisp and fuzzy site section methods. Additionally, the risk attitudes of decision makers are taken into account in the assessments of alternatives to reflect different levels of optimism. In order to do so, the rest of the paper is set out as follows. In Section 2, some basic concepts of 2-tuple and interval 2-tuple linguistic variables are briefly reviewed. In Section 3, an extended VIKOR for group decision making is developed to solve the group multi-criteria site selection problem with interval 2-tuple linguistic information. A numerical example is provided in Section 4 to illustrate the developed methodology and the conclusions are drawn in Section 5.

2. Preliminaries

2.1. 2-Tuple linguistic variables

The 2-tuple linguistic representation model was firstly presented in [22] based on the concept of symbolic translation. It is used to represent the linguistic information by means of a linguistic 2-tuple, (s, α), where s is a linguistic term from the predefined linguistic term set S and α is a numerical value representing the symbolic translation. In other words, a 2-tuple linguistic variable can be denoted as (s_i, α_i), $s_i \in S$, where s_i represents the central value of the ith linguistic term and α_i indicates the distance to the central value of the ith linguistic term.

In the 2-tuple linguistic approach proposed by Herrera and Martínez [22], the range of β is between 0 and g, which is relevant to the granularity of the linguistic term sets. Here, β is the result of an aggregation of the indices of a set of labels assessed in a linguistic term set S. For overcoming the restriction, Chen and Tai [41] proposed a generalized 2-tuple linguistic model and translation functions.

Definition 1. Let $S = \{s_0, s_1, \ldots, s_g\}$ be a linguistic term set and $\beta \in [0, 1]$ a value representing the result of a symbolic aggregation operation. Then the generalized translation function Δ used to obtain the 2-tuple linguistic variable equivalent to β can be defined as follows [41,42]:

$$\Delta : [0, 1] \rightarrow S \times \left[-\frac{1}{2g}, \frac{1}{2g}\right) \quad (1)$$

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