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An integrated decision making approach for assessing healthcare waste treatment technologies from a multiple stakeholder

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ABSTRACT

With increased worldwide awareness of environmental issues, healthcare waste (HCW) management has received much attention from both researchers and practitioners over the past decade. The task of selecting the optimum treatment technology for HCWs is a challenging decision making problem involving conflicting evaluation criteria and multiple stakeholders. In this paper, we develop an integrated decision making framework based on cloud model and MABAC method for evaluating and selecting the best HCW treatment technology from a multiple stakeholder perspective. The introduced framework deals with uncertain linguistic assessments of alternatives by using interval 2-tuple linguistic variables, determines decision makers' relative weights based on the uncertainty and divergence degrees of every decision maker, and obtains the ranking of all HCW disposal alternatives with the aid of an extended MABAC method. Finally, an empirical example from Shanghai, China, is provided to illustrate the feasibility and effectiveness of the proposed approach. Results indicate that the methodology being proposed is more suitable and effective to handle the HCW treatment technology selection problem under vague and uncertain information environment.

1. Introduction

Over the past decade, the amount of healthcare wastes (HCWs) generated worldwide rising quickly as the population, the number of healthcare facilities and the demand for medical services increase (Aghajani Mir et al., 2016; Thakur and Ramesh, 2015; Windfeld and Brooks, 2015; Zhang and Huang, 2014). In the developing world, the trend away from multi-use medical devices towards safer, single use is another driver of increasing HCW production. As a result, HCW management has become a complex and demanding challenge facing municipalities, particularly in the developing nations like China where HCW is very often mixed with municipal waste (Alagöz and Kocasoy, 2007; Gai et al., 2010; Yong et al., 2009). According to the World Health Organization (WHO), HCW is defined as the waste generated in the diagnosis, treatment or immunization of human beings or animals, including sharps, blood, body parts, chemicals, pharmaceuticals, medical devices and radioactive materials (Komilis et al., 2012). The disposal of HCWs is a high priority public health and environmental concern all over the world since, if not properly handled, it represents a significant risk of infection or injury to healthcare personnel and general public (Giacchetta, 2013; Mohee, 2005). Owing to these reasons, the management of HCWs has received an increasing amount of attention from both academic and practical fields (Alagöz and Kocasoy, 2008; Caniato et al., 2015; Hossain et al., 2011; Soares et al., 2013; Yang et al., 2009).

HCW management is a complex process consisting of waste collection, transfer routes, disposal plant location, treatment technology selection, and energy recovery. Because of the magnitude of its ecological and financial impacts, the selection of the best and most effective treatment technology for HCWs has been a subject of intense research interest. Generally, evaluating HCW treatment alternatives is a major complex problem to which multi-criteria decision making (MCDM) tool can be of a great help (Dursun et al., 2011b; Lu et al., 2016). Additionally, in many HCW treatment technology selection problems, decision makers may have difficulty in evaluating alternatives with specific crisp values due to the vagueness of human thinking. As is stressed by some researchers (Dursun et al., 2011a; Liu et al., 2015, 2014c), certain situations exist in which it is more suitable for decision makers to give their judgements by means of linguistic terms rather than numerical values. Moreover, the assessment information given by decision makers may be between two linguistic ratings in view of the complexity of certain HCW treatment technology selection problems.

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From the above discussions, it is clear that the methods of addressing HCW treatment technology selection problems are not yet fully developed, and there is a need to develop new and effective approaches for the assessment of HCW disposal methods with uncertain linguistic information. This article aims to propose an integrated decision support framework based on cloud model theory and the multi-attributive border approximation area comparison (MABAC), a new MCDM method recently developed by Pamučar and Ćirović (2015), for prioritizing and choosing the best HCW treatment alternative under uncertain linguistic environment. The overall contribution of this study to the knowledge area is threefold: (1) to determine the weights of decision makers objectively based on the concepts of interval 2-tuple linguistic variables; (2) to analyze the fuzziness and randomness of decision makers' linguistic expressions by using the cloud model; and (3) to rank the performance of different HCW disposal technologies by developing an extended MABAC method. Besides, in practice, several stakeholders such as municipalities, ministries, investors, and neighborhood population can be involved or impact the selection of a HCW disposal strategy. Therefore, this study also analyzes the available disposal alternatives for HCWs from the perspectives of multiple stakeholders.

The remainder of this paper is organized as follows. Section 2 reviews the related literature on current methods for HCW treatment technology selection and applications of cloud model theory. Section 3 gives a brief introduction about interval 2-tuple linguistic variables, cloud model theory, and transformation between them. In Section 4, we develop the HCW treatment technology selection model with cloud model and an extended MABAC method from a multiple stakeholder perspective. An empirical case study is given in Section 5 to illustrative the proposed decision support framework, in which sensitivity analysis of the results and comparative analysis with other existing methods are also provided. The managerial implications of the proposed work are drawn in Section 6, and finally, some conclusions are presented in Section 7.

2. Literature review

2.1. HCW treatment technology selection

To date, much progress has been made in research relating to the HCW disposal technology selection and a variety of decision support methods have been developed in the literature, particularly with MCDM methods. For example, Dursun et al. (2011b) proposed a fuzzy MCDM method based on the principles of fuzzy measure and fuzzy integral to identify the most suitable HCW treatment alternative for Istanbul. Karagiannidis et al. (2010) applied the analytic hierarchy process (AHP) technique for the effective planning and integrated assessment of scenarios on thermal processing of infectious hospital wastes, and Brent et al. (2007) adopted the AHP method to establish HCW management systems that minimize infection risks in developing nations. Dursun et al. (2011a) developed two MCDM frameworks using multi-level hierarchical structure and fuzzy set theory for the multi-attribute assessment of HCW disposal alternatives. Liu et al. (2013) presented a VIKOR-based fuzzy MCDM method for ranking HCW treatment technologies, in which linguistic terms are employed to assess the feasible disposal options and the ordered weighted averaging (OWA) operator is used to aggregate the individual assessments of decision makers. In addition, Liu et al. (2014c) evaluated HCW disposal strategies by applying a modified MULTIMOORA method called interval 2-tuple linguistic MULTIMOORA, and Liu et al. (2015) selected the appropriate HCW treatment alternative based on a hybrid MCDM model integrating the 2-tuple DEMATEL technique and the fuzzy MULTIMOORA method. Ciplak (2015) identified the best available HCW management option in the Turkish West Black Sea Region with the assistance of a multi-criteria decision analysis framework. Lu et al. (2016) proposed a hybrid decision making approach combining interval 2-tuple induced distance operators with the TOPSIS method for tackling HCW treatment technology selection problems with linguistic information.

2.2. Application of cloud model theory

Cloud model (Li et al., 2009) is a method for linguistic computation developed on the basis of probability theory and fuzzy set theory, which can describe the uncertainty of the qualitative concept perfectly and make the transformation between quantitative values and qualitative concepts much easier (Wang et al., 2015a, 2015b). In recent years, the cloud model has been utilized by a lot of authors to propose new solutions for uncertain linguistic MCDM problems. For instance, Wang et al. (2016) proposed a cloud model-based model for water quality assessment and tested it by evaluating the eutrophication status of 12 typical lakes and reservoirs in China. Chang and Wang (2016) proposed a group decision making approach for teacher evaluation in higher education based on cloud model and decision tree. Wu et al. (2016a) developed an integrated decision making framework based on cloud model and 2-order additive fuzzy measure for waste-to-energy plant site selection. Wu et al. (2016b) proposed a preference ranking organization method for enrichment evaluations (PROMETHEE)-based approach combined with cloud model for the optimal site selection of electric vehicle charging stations. Wang et al. (2015a) introduced a decision making method based on cloud model to deal with multi-criteria group decision making problems with uncertain linguistic information, and Wang et al. (2015b) applied the trapezium cloud model to propose a decision making method which can provide solutions to MCDM problems with interval-valued intuitionistic linguistic information. Zhao and Li (2015) used a hybrid risk evaluation model based on cloud model and fuzzy comprehensive evaluation method to analyze the risk in ultra high voltage (UHV) power construction projects. Besides, Li et al. (2014) applied a group assessment approach based on cloud model and VIKOR method to the risk management of informatization project under linguistic environment.

As reviewed previously, although many MCDM methodologies have been adopted in previous researches for the selection of HCW treatment technologies, to the best of our knowledge, no study has been conducted on the application of the MABAC method in HCW management problems. In addition, the cloud model is an excellent tool for expressing the uncertainty of qualitative concepts, which can realize the bidirectional transformation between qualitative information and quantitative data. Therefore, we propose an integrated decision making framework using cloud model and MABAC method for evaluating and selecting the best HCW treatment technology under uncertain linguistic environment. Additionally, the prior HCW treatment technology selection methods only consider the situations where the information about expert weights is completely known; no or little attention has been paid to the HCW management problems in which the decision makers' weights are unknown. In our proposed approach, the weights of decision makers are determined objectively by calculating the uncertainty and divergence degrees of the decision makers.

3. Preliminaries

3.1. Interval 2-tuple linguistic variables

Let $S = \{s_0, s_1, \ldots, s_g\}$ be a finite and totally ordered discrete linguistic term set, where g is an even integer and s_i denotes a possible value of a linguistic variable, then the linguistic term set

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