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A novel trapezoidal intuitionistic fuzzy information axiom approach: An application to multicriteria landfill site selection

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ABSTRACT

Information axiom is used to determine the best option among the potential alternatives. In case of uncertain parameters, information axiom has been extended to its ordinary fuzzy versions in the literature. In this paper, we developed a trapezoidal intuitionistic fuzzy information axiom model in order to handle the hesitancy of experts. The developed model aggregates the judgments of more than one expert and proposes a new defuzzification method for trapezoidal intuitionistic fuzzy sets. Our model was applied to a multicriteria landfill site selection problem and a sensitivity analysis was conducted to check the robustness of the given decisions.

1. Introduction

Information axiom (IA) is the second axiom of the axiomatic design which is used to determine design characteristics (Suh, 1990). IA measures the information content of any design based on satisfaction degree between design and system ranges. It is frequently used as a decision making tool to select the best design that satisfies independence axiom. The main advantage of information axiom method is to enable the decision makers to define the desired characteristics for the considered criteria. In addition, each alternative has its own system characteristics. There is a need for a method which can measure the overlapping levels of these two sets of characteristics. Especially, when the characteristics cannot be defined precisely, fuzzy information axiom provides an excellent tool for measuring uncertain overlapping levels. In the literature, IA is extended to its fuzzy versions in order to capture impreciseness and vagueness in design problems. Hence, fuzzy information axiom (FIA) has been drawing attention in the literature with its wide variety of applications (Kulak et al., 2010). It guides decision makers to define decision requirements via functional requirements (FR) in order to minimize information content of the design. Ordinary fuzzy information axiom models have been used in the solution of product service system development problem (Chen et al., 2015), public transportation investment problem (Kaya et al., 2012), decision support system development problem (Cebi and Kahraman, 2010), ship design problem (Cebi et al., 2010, 2012), transportation company selection problem (Kulak and Kahraman, 2005a), and advanced manufacturing system selection problem (Kulak and Kahraman, 2005b).

A landfill site is defined as a site for the disposal of waste materials by using various methods. Landfill sites are required to dispose of waste materials that it is impossible or hard to be reused or recycled. Although governments spend time and money for developing new technologies in order to reduce the amount of waste materials, there is still being huge quantity of waste materials coming from both household and commercial sector. Therefore, determining the best site for landfill facility is a critical issue in urban planning process since it includes vital impact on the economy, ecology, and the environmental health of the region. The main purpose in the landfill site selection process is to determine the best location that minimizes hazards to the environment and public health (Uyan, 2014). The determining of an optimum location for landfill among potential alternative locations is a multiple criteria decision-making problem including both quantitative and qualitative criteria. Since the measurements of qualitative criteria include imprecise or vagueness, the conventional approaches to facility location problem tend to be less effective in dealing with these impreciseness or vagueness (Kahraman et al., 2003).

Ordinary fuzzy set theory proposed by Zadeh (1965) has been used in order to cope with vagueness or uncertainty in human thinking process. However, it is hard to define an exact membership function by using ordinary fuzzy sets when there is some hesitancy of experts. Therefore, the membership and non-membership functions of a fuzzy set are simultaneously defined in an intuitionistic fuzzy set (IFS). IFS requires sum of degrees of membership and non-membership values of

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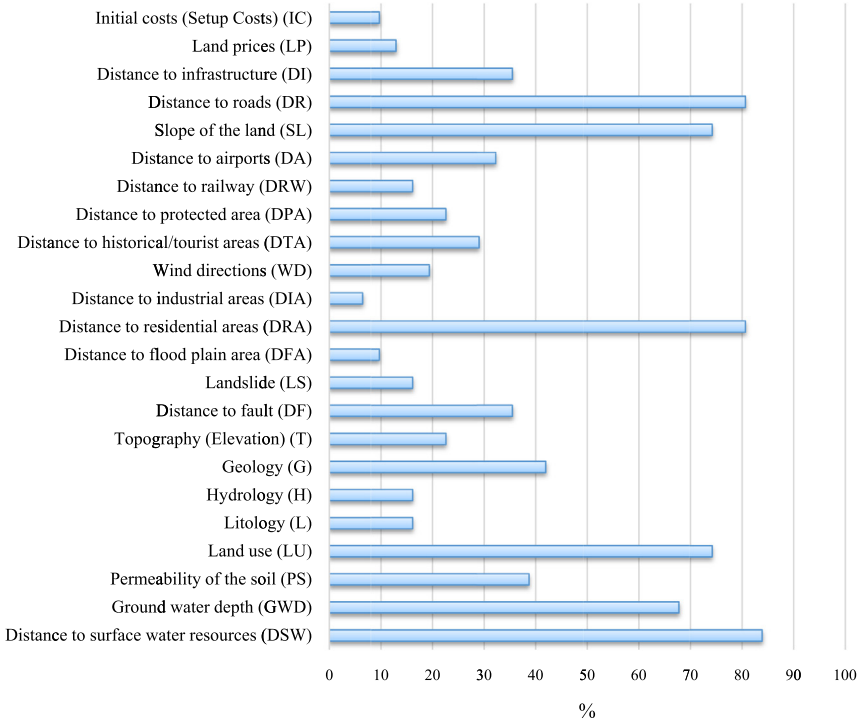

Fig. 1. Usage percentages of the evaluation criteria.

any element to be at most equal to 1. IFSs are the excellent extension of fuzzy sets that can consider the experts' hesitancy and vagueness together. IFSs have been later extended to Pythagorean fuzzy sets in order to provide a larger range for membership degrees (Yager, 2013). Intuitionistic and Pythagorean fuzzy judgments assigned by different experts can be aggregated by various aggregation functions (Garg, 2016, 2017a, b; Garg and Arora, 2017; Garg et al., 2017).

The contribution of the proposed multicriteria information axiom method is the captured uncertainty and hesitancy in decision-making process through intuitionistic fuzzy sets. The incorporation of experts' hesitancies into the decision model is the main research area of the recently developed fuzzy set extensions such as intuitionistic fuzzy sets, type-2 fuzzy sets, hesitant fuzzy sets, Pythagorean fuzzy sets, etc. Information axiom measures the information content which indicates the best design with the highest probability of success. It compares the design range and system range and selects the best alternative as the one having the most overlapped ranges. The proposed method is different from the other approaches since decision-making is based on the comparisons of these ranges.

In the literature, there are several ordinary FIA works that try to capture the vagueness and impreciseness in the definition of system and design requirements. However, these works cannot address the hesitancy of experts. The motivation of our study is to develop intuitionistic trapezoidal FIA in order to consider this hesitancy. It is the first time that FIA is extended to intuitionistic trapezoidal fuzzy sets in this paper. For this purpose, new definitions and formulas for FIA will be presented. In addition, an original area based defuzzification method has been proposed to the literature. In the scope of this paper, landfill site selection problem will be solved by using the proposed trapezoidal intuitionistic fuzzy information axiom.

The rest of this paper is organized as follows. Section 2 presents a literature review for multicriteria landfill site selection. Section 3 gives the evaluation criteria for landfill site selection problem. Section 4 presents the basics of fuzzy information axiom method. Section 5 provides intuitionistic sets and Section 6 proposes intuitionistic fuzzy information axiom. Section 7 presents the solution of a landfill site selection problem and a sensitivity analysis. Finally, the concluding remarks are given in Section 8.

2. Literature review: Multicriteria landfill site selection

The waste management process is a vital problem for urban planning and it includes various steps which are collection, transport, processing, recycling or disposing, and monitoring. The effectiveness of this process is based on the selection of the most suitable landfill site. An inappropriate decision on landfill site selection has negative impacts on environmental, economical, and social factors (Moghaddas and Namaghi, 2011; Nazari et al. 2012). The solution of this problem is hard, complex, and time-consuming process because of the evaluation of various conflicting criteria. Therefore, during the last decade, the problem has attracted a lot of research works and academic studies. The list of the most common used criteria in the literature is given in Table 1. According to the table, the most preferred criteria are *Distance to surface water resources (DSW)*, *Distance to roads (DR)*, *Distance to residential areas (DRA)*, *Land use (LU)*, and *Slope of the land (SL)*, respectively. The usage percentages of the evaluation criteria are presented in Fig. 1.

Table 2 presents the methods used for the evaluation of landfill site selection problem. In the literature, different models and methods are used in order to determine appropriate site for landfill. An integrated method combining analytic hierarchy process (AHP) and geographic information system (GIS) is the most preferred method in the literature. Additionally, some other site selection methods such as genetic algorithms (Lee et al., 2010), regression based methods (Bilginol et al., 2015), spatial multi-criteria analysis (van Haaren and Fthenakis, 2011), agent based models (Sirikijpanichkul et al., 2007), and fuzzy based models (Nazari et al., 2012) can be used for landfill site selection. Fig. 2 presents the usage percentages of evaluation methods in the literature.

3. Evaluation criteria for landfill site selection

In the literature, there are lots of criteria that have been considered for the solution problem. In the scope of this study, the criteria affecting the selection of a landfill site are classified into three main groups. These groups are *Environmental factors*, *Social factors* and *Economical factors*. Definition of these criteria and their design ranges are as follows: