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Soft computing based on hierarchical evaluation approach and criteria interdependencies for energy decision-making problems: A case study

Hossein Gitinavard [a], S. Meysam Mousavi [b, *], Behnam Vahdani [c]

[a] Young Researchers and Elite Club, South Tehran Branch, Islamic Azad University, Tehran, Iran
[b] Department of Industrial Engineering, Faculty of Engineering, Shahed University, Tehran, Iran
[c] Faculty of Industrial and Mechanical Engineering, Qazvin Branch, Islamic Azad University, Qazvin, Iran

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In numerous real-world energy decision problems, decision makers often encounter complex environments, in which existent imprecise data and uncertain information lead us to make an appropriate decision. In this paper, a new soft computing group decision-making approach is introduced based on novel compromise ranking method and interval-valued hesitant fuzzy sets (IVHFSs) for energy decision-making problems under multiple criteria. In the proposed approach, the assessment information is provided by energy experts or decision makers based on interval-valued hesitant fuzzy elements under incomplete criteria weights. In this respect, a new ranking index is presented respecting to interval-valued hesitant fuzzy Hamming distance measure to prioritize energy candidates, and criteria weights are computed based on an extended maximizing deviation method by considering the preferences experts' judgments about the relative importance of each criterion. Also, a decision making trial and evaluation laboratory (DEMATEL) method is extended under an IVHF-environment to compute the interdependencies between and within the selected criteria in the hierarchical structure. Accordingly, to demonstrate the applicability of the presented approach a case study and a practical example are provided regarding to hierarchical structure and criteria interdependencies relations for renewable energy and energy policy selection problems. Hence, the obtained computational results are compared with a fuzzy decision-making method from the recent literature based on some comparison parameters to show the advantages and constraints of the proposed approach. Finally, a sensitivity analysis is prepared to indicate effects of different criteria weights on ranking results to present the robustness or sensitiveness of the proposed soft computing approach versus the relative importance of criteria.

1. Introduction

Since the beginning of civilization, energy resources have been important issues for humans and countries. In this regard, renewable energies are known as one of significant key factors for economical and social development and for future life. The renewable energies could lead to reducing production costs [23], and air pollution, reducing environmental pollution, and saving the non-renewable energies [55]. For this purpose, selecting the most suitable energy candidate in terms of the conflicting evaluation criteria could help energy decision makers (DMs) in many countries to choose the best policy for their productions, consumptions, and the supply of energies. To address the issue, decision-making analysis can be regarded as one of the important approaches, which could appropriately assess energy sector policies and renewable energy candidates. In this respect, multiple attributes decision-making (MADM) methodologies are significant parts of the research that has evaluated and ranked possible energy alternatives and then have chosen the best one.

In classical MADM problems, the evaluation of possible energy alternatives are precisely known [35]. In addition, when the complexity of real-world decision-making problems has increased, several DMs or experts might be considered to evaluate the problem which is known as multi-criteria group decision making (MCGDM) process. Hence, some authors have considered the MADM/MCGDM techniques to solve their energy problems based on the precise information. Akash et al. [2] implemented the analytical hierarchy process (AHP) method to evaluate and report

* Corresponding author.
E-mail address: sm.mousavi@shahed.ac.ir (S.M. Mousavi).

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the electricity power production elements in Jordan. Afgan and Carvalho [1] provided the choice of criteria based on the analysis and synthesis of parameters to assess the renewable energy technologies regarding to economic indicators, environment capacity, energy resources, and social indicators. Ulutas [38] applied the analytical network process (ANP) method to select the most appropriate energy policy and to determine suitable energy resource candidate by considering the conflicting selection criteria in Turkey. Patlitzianas et al. [30] proposed an integrated decision-making analysis approach based on ordered weighted average of qualitative judgments to achieve the renewable energy producers in the European Union Accession. In addition, Wang et al. [42] developed a hierarchical decision-making method to assess the non-renewable and renewable energy resources in China. Vahdani et al. [40] regarded the decision problem of alternative-fuel buses evaluation by two MCDM techniques. Also, several types of fuels, including electricity, fuel cell (hydrogen) and methanol, were taken into account as fuel modes. Erol and Kılkıs [11] utilized the AHP method to assess three energy source policy candidates as long-term, sustainable, and robust in Turkey. Yazdani-Chamzini et al. [51] presented an integrated decision-making method based on the complex proportional assessment (COPRAS) and AHP methods to choose the best renewable energy project. Doukas et al. [10] developed a transparent methodological decision framework regarding to linguistic terms for obtaining the environmental corporate policies and companies' energy. Georgiou et al. [13] implemented the preference ranking organization method for enrichment of evaluation (PROMETHEE) and AHP methods to compare the ranking results of the best renewable energy.

In most hesitant and complex situations, involved parameters may be uncertain or imprecise, and DMs or experts cannot express their opinions by crisp values [26]. Hence, the DMs' judgments are expressed based on the preferences through decision-making regarded as fuzzy values, and some of the values may be expressed as linguistic terms [29], for instance, intuitionistic fuzzy sets [39], interval-valued intuitionistic fuzzy sets [16], interval-valued fuzzy sets [41], hesitant fuzzy sets [54], and interval-valued hesitant fuzzy sets [12], to cope with the uncertain conditions.

To deal with the above-mentioned issues, some researchers have considered the fuzzy information to solve the imprecise energy problems. Goumas and Lygerou [14] developed the fuzzy PROMETHEE technique to rank and evaluate the candidates of energy exploitation schemes in geothermal field. Kahraman et al. [20] presented the axiomatic design (AD) and AHP methods based on the fuzzy information to assess the renewable energy candidates under the objective and subjective criteria. Meixner [24] focused on a fuzzy AHP method to select the most appropriate energy source candidate. Kahraman and Kaya [19] developed a fuzzy MCDM methodology according to AHP method to select the best policy among the energy policies candidates. Kaya and Kahraman [22] proposed an integrated fuzzy VIKOR (vlsekriterijumska optimizacija i kompromisno resenje in serbian) and AHP method to specify the most suitable renewable energy candidate in Istanbul. Kaya and Kahraman [21] concentrated on a modified fuzzy TOPSIS (the technique for order of preference by similarity to ideal solution) method to choose the best energy technology candidate. In the study, the criteria weights were computed based on the fuzzy pair-wise comparison matrices. Jing et al. [18] proposed a fuzzy integrated evaluation model based on the MCDM procedure to obtain the comprehensive merits of combined heating, cooling and power systems. Sadeghi et al. [33] applied a fuzzy AHP method to specify the criteria weights and then implemented the TOPSIS method to assess renewable energy sources problem in Iran. Ansari and Ashraf [3] implemented a fuzzy MCDM method to select the suitable energy source for electricity generation in India. Cavallaro [7] and Sianaki and Masoum [34] focused on a TOPSIS method under a fuzzy environment to assess the nuclear energy competitiveness.

In addition, to deal with uncertain situations, recently, Torra and Narukawa [37] and Torra [36] have introduced hesitant fuzzy sets (HFSs), in which experts or DMs could offer their evaluations under a set of membership degrees to margin of errors. Indeed, this theory as an appropriate logic is more attention by many scholars in the recent years. In this respect, Zhang [58] has introduced some power aggregation operators and developed them to a hesitant fuzzy environment; also, the new aggregation operators to develop techniques has been utilized for the multiple attributes group decision-making (MAGDM). Xia et al. [45] have studied on the aggregation operators of the hesitant fuzzy information and proposed several aggregation operators; then, relation between them has been discussed. Chen et al. [9] have considered the variation of opinions among several experts or DMs; on the other hand, an approach to the GDM has been extended under interval-valued hesitant preferences relations. Rodriguez et al. [32] have introduced a linguistic group decision model for flexible linguistic expressions according to hesitant fuzzy linguistic term sets. Zhang et al. [59] have developed series of aggregation operators under hesitant fuzzy or interval-valued hesitant fuzzy environments; also, they used this operation to solve MAGDM problems.

The survey of the literature indicated that fuzzy sets theory could successfully be implemented to deal with uncertain situations. Hence, the HFS among extensions of fuzzy sets is a useful tool by assigning some membership degrees for an energy candidate versus the conflicting criteria under a set. Some researchers have considered the HFS theory to solve the decision-making problems in the field of energy. For instance, Xu and Zhang [49] developed the TOPSIS method based on HFS and IVHFS under incomplete information to evaluate the energy policy selection problem. Öztayşi and Kahraman [28] presented a fuzzy decision-making methodology to evaluate the renewable energy candidates, in which the criteria weights and the candidate rankings were determined based on the interval-valued type-2 fuzzy AHP and hesitant fuzzy TOPSIS methods, respectively. Zhang and Xu [57] proposed a hesitant fuzzy interval programming technique regarding to linear programming model for preference multi-dimensional analysis to solve the energy project selection problem. Yao and Li [50] presented an evaluation method based on hesitant fuzzy information for new energy in regional sustainable development. Mousavi and Tavakkoli-Moghaddam [25] proposed a hesitant fuzzy hierarchical COPRAS method by regarding subjective and objective judgments to solve the renewable energy selection problem in Iran. In their study, the criteria and DMs' weights were computed based on a hesitant fuzzy index and hesitant fuzzy entropy method, respectively.

In some situations, the relative importance of criteria may be unknown or incomplete; then, some methods have been proposed to determine these values under uncertainty. Xu [46] has introduced some approaches for estimating the attributes weights; then, with establishing an optimization model based on ideal point of attributes' values, these weights have been determined. Wei [43] has estimated the weight vector of attributes by utilizing an optimization model based on the TOPSIS method. Wei et al. [44] have proposed an optimization model for determining the attributes weights based on the max-min operator and the negative ideal solution. Also, Xu and Zhang [49] have proposed an optimization model according to the maximizing deviation method that could be determined by attributes weights under situations, in which the information about attributes weights were completely unknown or

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