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A combined fuzzy approach to determine the best region for a nuclear power plant in Turkey

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ABSTRACT

When increase in energy needs of developing countries cannot be met by conventional energy sources, alternative energy sources are considered to substitute them. Nuclear energy that meets the needs of a greater proportion of energy demands for countries is one of effective alternative energy types. In this context, after deciding on the use of nuclear energy, the selection of the most suitable location for the production of nuclear power is one of the important decision making problems. In this paper, we performed a facility location selection model for Turkey in meeting the needs of energy with using new and unused source of nuclear energy. For this aim, a combined fuzzy multi criteria decision making (MCDM) methodology that consists of Interval type-2 fuzzy analytical hierarchy process (AHP) that is applied to determine weights of criteria and interval type-2 fuzzy TOPSIS that is applied for ranking alternatives is used to determine the best location alternative for the nuclear power plant. By the way, the obtained results have been analyzed depending upon the criteria that used for the evaluation process. The obtained results are compared with existing nuclear power plants location selection policy for Turkey and some suggestions have been made for the plants where would be the located are not decided. By the way, a sensitivity analysis has been conducted to analyze effects of changes in decision's parameters.

1. Introduction

Q4 To provide energy needs is a major problem for all countries around the world in recent years. In particular, the oil bottleneck, which is emerged at the beginning of the 1970s, accelerate this seeking and procure nuclear as a reliable source of energy has come to the forefront. Turkey's basic energy strategy to meet our energy demand is to reduce external dependency and the adopted policies can be list as [1]:Ensuring the country of origin and route diversity,Increasing energy efficiency,Reduction of energy density,Using of all domestic resources,And in 2023, the share of renewable energy sources in electricity production to be increased to at least 30%.

Nuclear technology is meeting the 17% of the world's electrical requirements. Today, more than 30 countries are operating nuclear power plant. Worldwide, more than 1000 commercial, military and research nuclear reactor is operated [2]. Nuclear energy has also great importance in terms of ensuring our energy supply security for countries, decreasing dependence on imported energy and reducing the current account deficit. For all these reasons, nuclear power plant installation work has begun in Sinop and Akkuyu for Turkey [1]. Many factors in the selection of these two regions were taken into consideration. In this paper, we try to find these selected regions whether the most appropriate regions or not and to make some suggestions for new nuclear power plant alternatives by using our suggested fuzzy multi criteria decision making (MCDM) methodology.

Several criteria must be considered in the analysis of many real-world decision making problems [50]. Selection of appropriate locations for facilities is an important engineering problem which has many factors both qualitative and quantitative. Facility location problem is a typical MCDM problem which involves many conflicting attributes [3]. Facility location problem includes conflicting criteria such as political environment, proximity to markets and customers, supplier networks, expansion potential, availability of transportation systems and utility, quality-of-life issues, culture issues, etc. Choosing a location for the power plant affecting the state's energy policy is a strategic decision. Especially, selection of nuclear energy power plant, which has a high interaction with surroundings, is a decision that should be analyzed well. If the location of nuclear power plants cannot be selected correctly, it can lead to many problems such as unnecessary transportation costs, unavailability of qualified labor, raw material supply problems and loss of competitive advantage [4]. During the evaluation

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process of problem discussed, because all the criteria cannot be are expressed numerically, human judgment is needed and so applying the fuzzy sets will provide more accurate results. In modeling real world problems, using linguistic assessments is more reasonable instead of using numerical values when our knowledge is fuzzy. Different decision making tools can be extended to fuzzy environment. Fuzzy numbers can be applied used to establish decision making approaches [51].

Therefore we have discussed to find the most appropriate nuclear power plant location alternative for Turkey with using a fuzzy MCDM methodology based on type-2 fuzzy sets.

Using MCDM methods for the selection of facility location problems is a common approach that is adopted for many years by researchers. There are many papers that propose MCDM methods both facilities and power plant location selection. For example, Chakraborty et al. [5] presented four well-known MCDM methods that applied on a facility location selection problem and their relative ranking performances are compared. Aksu and Ocak [6] proposed a methodology to determine the locations of municipal centers for eight newly established counties within the Istanbul Metropolitan Municipality. Athawale et al. [7] presented an approach solves two real time facility location selection problems using preference ranking organization method for enrichment evaluation (PROMETHEE II) method which is observed to an effective MCDM tool often applied to deal with complex problems in the manufacturing environment. They compared the ranking performance of PROMETHEE II method with the other MCDM methods and observed that the top-ranked alternatives exactly match with those as obtained by the past researchers. Özdağoğlu [8] proposed a fuzzy ANP method for a multi-criteria facility location selection problem where the criteria set includes interactions with each other on the hierarchy structure. Ertuğrul [9] proposed a method which is fuzzy group decision making based on extension of TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method has been applied to a facility location selection problem of a textile company in Turkey. Kahraman et al. [10] presented different approaches and techniques used in location selection problems, especially on the fuzzy MCDM methods. Boran [4] presented the integration of intuitionistic fuzzy preference relation aiming to obtain weights of criteria and intuitionistic fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method aiming to rank alternatives for dealing with imprecise information on selecting the most desirable facility location and a practical application is given to illustrate the application of the proposed method. Hu et al. [11] proposed a fuzzy TOPSIS method for distribution center location selection. Ertuğrul and Karakaşoğlu [12] presented the use of fuzzy AHP and the fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methods for the selection of facility location.

Besides all these, some studies related directly to the location selection of nuclear power plants. Rechard et al. [13] summarized the historical events from the identification of the Yucca Mountain site in southern Nevada in 1978 to its selection by the US Congress as the sole site to characterize for a repository for spent nuclear fuel and high-level radioactive waste in 1987. Erdoğan and Kaya [14] proposed a fuzzy MCDM model for the nuclear power plant site selection in Turkey. Locatelli and Mancini [15] proposed a two-step framework to choosing the best nuclear reactor at the pre-feasibility study phase. Wu et al. [16] proposed a method which used firstly AHP to establish index system for inland nuclear station location; secondly establishes the evaluation model based on the gray comprehensive evaluation method; and finally applies the model to one location of a nuclear power station for instance, which confirm the feasibility of the model. Erol et al. [17] developed a fuzzy MCDM approach to select nuclear power plant location in Turkey. Their proposed framework employed fuzzy entropy and fuzzy compromise programming. Wu et al. [18] adopts the fuzzy mathematical theory, and suggests a combination of fuzzy comprehensive evaluation and AHP to determine the best plan for site selection of a nuclear power plant. Idris and Abd. Latif [19] presented the role of AHP and GIS in determining the optimum location of nuclear power plant, criteria for the site selection and the results for finding the optimum location of nuclear power plant. Ekmekçioğlu et al. [20] proposed fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) integrated with fuzzy AHP (analytical hierarchy process) methodology to develop fuzzy multi-criteria SWOT analysis in order to selection of nuclear power plant site. Rechard et al. [21] proposed a process for site selection, characterization, and research and development for spent nuclear fuel and high-level waste disposal. Duncan et al. [22] presented that the bedrock around the determined coordinates is suitable for retarding radionuclide migration over a significant time period, and a repository design for the considered geological conditions. Li and Su [23] proposed a model to evaluate placement schemes of nuclear power plant planning by game theory, and optimal mathematical model and corresponding algorithm for the game of site selection of nuclear power plant to implement optimal planning. Shaver and Facella [24] proposed a process of site selection serves as the road map for decision-making on the location for the deep geological repository for Canada. Krütli et al. [25] proposed a procedure with a functional-dynamic view of public participation that combines the decision-making process (DMP) with specific types and extents of public participation and illustrate their arguments using a proposed site selection process for nuclear waste. Megahed [26] summarized the main findings of the feasibility study of nuclear power and desalination plant on El-Dabaa site. Kurt [27] presented fuzzy TOPSIS and generalized Choquet fuzzy integral algorithm for evaluation and selection of optimal locations for nuclear power plant in Turkey.

Sanchez et al. [28] determined a technique for forming information granules based on the theory of uncertainty-based information. Hernandez et al. [29] proposed a hybrid learning method for interval A2-C1 type-1 non-singleton type-2 TSK fuzzy logic system that uses the recursive orthogonal least-squares algorithm to tune the type-1 consequent parameters, and the back-propagation algorithm to tune the interval type-2 antecedent parameters. Melin and Castillo [30] presented a review of type-2 fuzzy logic applications in pattern recognition, classification and clustering problems. Cortes-Rios et al. [31] proposed an extension of the simple tuning algorithm for fuzzy logic controllers based on the theory of type-2 fuzzy systems by using a parallel model implementation. Mendez et al. [32] presented the so-called interval type-1 non-singleton type-2 fuzzy logic roll gap controller.

Also, the papers that are using type-2 fuzzy TOPSIS, type-2 fuzzy AHP and the combination of these two fuzzy techniques in MCDM problems are available. Kiliç and Kaya [33] proposed a new evaluation model for investment projects for development agencies operating in Turkey. Because of the ambiguities and relativities in real world, they used composition of type-2 fuzzy AHP and type-2 fuzzy TOPSIS methods for the investment project evaluation problem. Abdullah and Najib [34] presented a new FAHP characterized by interval type-2 fuzzy sets for linguistic variables. The proposed model is illustrated by a numerical example of work safety evaluation. Kahraman et al. [35] proposed an interval type-2 fuzzy AHP method together with a new ranking method for type-2 fuzzy sets and they applied the method to a supplier selection problem. Chen [36] presented the interval type-2 fuzzy TOPSIS procedure to determine the priority ranking orders of the alternatives under consideration of the multiple criteria evaluation/selection. Dymova et al. [37] proposed an interval type-2 fuzzy extension of the TOPSIS method realized with the use of α-cuts representation of the interval type-2 fuzzy values. Erdogan

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