AN INTEGRATED MULTI-CRITERIA DECISION-MAKING METHODOLOGY BASED ON TYPE-2 FUZZY SETS FOR SELECTION AMONG ENERGY ALTERNATIVES IN TURKEY

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Abstract. Energy is a critical factor to obtain a sustainable development for countries and governments. Selection of the most appropriate energy alternative is a completely critical and a complex decision making problem. In this paper, an integrated multi-criteria decision-making (MCDM) methodology based on type-2 fuzzy sets is proposed for selection among energy alternatives. Then a roadmap has been created for Turkey. To overcome uncertainties in decision making process, the fuzzy set theory (FST) is suggested. For this aim, two of the most known MCDM methodologies are reconsidered by using type-2 fuzzy sets. Fuzzy Analytic Hierarchy Process (FAHP) based on interval type-2 fuzzy sets is constructed and is used to obtain the weights of the criteria affecting energy alternatives. To rank the energy alternatives, the other MCDM method that is Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is fuzzified by interval type-2 fuzzy sets. The proposed integrated MCDM methodology based on interval type-2 fuzzy sets is applied to obtain a road map of energy policies for Turkey."

1. Introduction

Countries require energy to sustain their social and economic lives. The demand for energy is increasing as a result of population growth, industrialization and urbanization. The main purpose of developing countries such as Turkey is to have enough amount of energy to provide economic development. This requires planning energy alternatives and effective and efficient use of them. Considering the strategic objectives of the country's energy planning becomes even more important. Fuel economy is growing rapidly in Turkey, the country's electricity consumption to rise by 8-9% on average each year [4]. According to the report prepared by Ministry of Energy, the State Planning Organization, under secretariat of Treasury and Energy Market Regulatory, Turkey's energy consumption by 2020 is estimated to rise to 222 million tons of oil in the high scenario and the low scenario is estimated to rise to 194 million tons of oil equivalent [45]. The increasing demand of energy in Turkey requires to clarify the most appropriate energy policy that is based on to decide which energy alternative must be invested. Since determination of correct energy policy is a so critical problem that involves multiple conflicting criteria, it is

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the best way to analyze energy investment or energy decision making problem by using multi-criteria decision making (MCDM) methods.

Multi-criteria decision-making (MCDM) is one of the most recognized branches of decision-making and involves selecting the best alternative based on a set of decision criteria and alternatives.[40]. MCDM methods aim to produce an approach by decision-makers to better understand the holistic approach that are tools to regulate the necessary information for decision-making [39]. Analytic Hierarchy process (AHP) is an approach that uses to solve MCDM problems. This method uses pairwise comparison matrices to reach final decision. It can be applied to both individual and group decisions[5]. It can be used to obtain a vector of priority weights in hybrid decision making models. Technique for order preference by similarity to ideal solution (TOPSIS) is another MCDM method for solving MCDM problems which is based to choose alternative should have the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution [17]. This technique is based on the concept that the ideal alternative has the best level for all attributes, whereas the negative ideal is the alternative with all of the worst attribute values [32]. Decision-making process is often composed of alternatives that bases on conflicting criteria that gain from hierarchical comparisons of options. Too many variables play a role in managing the decision-making process. Some of them can be handled by numerical models. Other variables can only be qualitatively assessed or with subjective judgment [3]. The second type of variables makes evaluation of process to more difficult and to uncertain. During evaluation stage of alternatives, it is difficult to use exact numerical values, so decision-makers define their preferences with linguistic variables in many decision-making problems. In this case, the fuzzy set theory (FST) that was introduced by Zadeh [55] is used to resolve the uncertainty [21]. MCDM methods are used with FST to obtain more realistic results. FST discusses to express of linguistic terms by using the membership functions[20, 29]. FST uses fuzzy sets, membership functions and fuzzy numbers to convert unclear information to useful data. The fuzzy sets are characterized by a membership function that assigns a membership value to alternatives and criteria between 0 and 1 [31]. The membership functions of traditional fuzzy sets are expressed in certain numbers. So these fuzzy sets are called as type-1 fuzzy sets. When it is aimed to reduce the level of uncertainty and prompt to get results closer to the truth, type-2 fuzzy sets can be applied. Type-2 fuzzy sets are the extension of type-1 fuzzy sets and this type of sets of membership functions are fuzzy itself [36]. In this paper, type-2 fuzzy sets are integrated with MCDM methodology to obtain more reliable, flexible and sensitive results. For this aim, AHP and TOPSIS methodologies are re-constructed under type-2 fuzzy sets and two new decision making methodologies are obtained. Then a new fuzzy decision making methodology based on type-2 fuzzy sets is obtained and is used to determine the most appropriate energy alternatives for Turkey.

For this aim, thirty five main criteria and sub-criteria that affect the selection of energy alternatives are determined as a result of the literature search. Then it is tried to get answer for the question of what is the most suitable energy alternative for Turkey with considering these criteria. According to reports from Ministry of

Energy in Turkey, the energy alternatives for Turkey are determined as solar, hydraulic, wind, biomass, geothermal, natural gas, oil and coal. In this paper, these are evaluated by using a MCDM method based on type-2 fuzzy sets. The rest of this paper is organized as follows: Section 2 includes a literature review about energy and energy decision making. Section 3 includes some details about the energy alternatives for Turkey. Section 4 explains the details of a new fuzzy MCDM method that is based on type-2 fuzzy sets and is firstly proposed in this paper. Section 5 presents a real case application to evaluate energy alternatives of Turkey. Finally, the results obtained and future research directions are discussed in Section 6.

1.1. **Literature Review.** The formulation of energy and environmental policies often involves many decision makers and can affect numerous stakeholders from heterogeneous constituencies with different value systems, and a number of different concerns about specific aspects of policy [15]. This situation enables to be applied decision-making methods in these problems. The use of decision-making methods has become popular in energy policy making problems in recent year. In this section, a literature review is briefly summarized to investigate the previous studies. Kahraman et al. [23] propose to develop an interval type-2 fuzzy AHP method together with a new ranking method for type-2 fuzzy sets. Balezentiene et al. [2] presented a MCDM framework for prioritization of energy crops based on fuzzy MULTIMOORA method which enables to tackle imprecise information. Garca-Cascales et al. [13] analyzed decision criteria to be used when searching for the best photovoltaic cell. They provided relevant information by three experts and the TOPSIS method has been used to aggregate all the information combined with the use of fuzzy sets. Jing et al. [18] presented an evaluation model that integrates FST with multi-criteria decision-making process to assess the comprehensive benefits of CCHP (combined cooling, heating and power) systems from technology, economic, society and environment criteria. They employed grey relation analysis and combination weighting method to compare the integrated performances of CCHP systems. Manzardo et al. [34] aimed to develop a grey-based group decision-making methodology for selection of the best renewable energy technology by using a life cycle sustainability perspective. They modified traditional grey relational analysis to better analysis of uncertainty. Lee et al. [29] presented an evaluation model, which incorporates interpretive structural modeling (ISM) and fuzzy analytic network process (FANP) to select suitable turbines of a wind farm. Sadeghi et al. [44] proposed a fuzzy multi-criteria decision-making (FMCDM) approach in order to evaluate alternative renewable energies in Yazd province in Iran. In this paper, two FMCDM methods that one was fuzzy AHP to determine the relative weights of the evaluation criteria and the second was extension of the fuzzy TOPSIS to rank the alternatives were used. They found that solar energy was the most appropriate renewable energy source for the studied area. Suo et al. [47] presented a case study of planning electric power problems for demonstrating the applicability of their proposed methodology. The proposed methodology was based on advanced ordered weighted averaging (AOWA) operator for tackling multi criteria decision making (MCDM) problems under uncertainties. Hsueh [16] presented an

integrated model that includes Delphi method, AHP, and FST to establish an energy conservation assessment model for households. Choudhary and Shankar [11] carried out an STEEP-fuzzy AHP-TOPSIS based framework for evaluation and selection of optimal locations for Thermal Power Plants. They identified potential feasible locations based on social, technical, economical, environmental, and political (STEEP) considerations. The fuzzy AHP was applied to determine the weights of qualitative and quantitative criteria impacting location selection process and TOPSIS was used to rank the alternative locations based on their overall performance. Chang et al. [8] presented an assessment model for evaluating hydrogen fuel cell applications and aimed to provide a screening tool for decision makers. For this aim, the fuzzy MCDM method was used to assess hydrogen fuel cell applications. They evaluated seven different hydrogen fuel cell applications based on 14 criteria. And their results showed that fuel cell backup power systems should be chosen for development in Taiwan. Ansari and Ashraf [1] proposed an application of a fuzzy MCDM methodology for selection of the best energy source for Electricity Generation in India. Daim et al. [12] presented a method to evaluate and select energy storage technologies for investor-owned or public utilities. They employed a technology evaluation process integrating with fuzzy Delphi method, AHP and fuzzy consistent matrix. According to their result, compressed air storage was the most promising technology for sustainable growth of renewable energy in the region they studied. Kang et al. [24] presented a comprehensive evaluation model to select a suitable location for developing a wind farm. Their model included interpretive structural modeling (ISM), benefits, opportunities, costs and risks (BOCR) and fuzzy analytic network process (FANP) methods. Mengi and Altas [38] proposed a smart energy management that consists of Photovoltaic/Wind (PV/W) renewable energy resources by using a fuzzy decision making (FDM) process. Kaya and Kahraman [26] aimed to generate a modified fuzzy TOPSIS methodology for the selection of the best energy technology alternatives. Lee et al. [29] proposed a strategic hydrogen energy technology roadmap by considering economic impact, commercial potential, inner capacity, and technical spin-off criteria. They suggested a methodology to prioritize the relative weights of hydrogen energy technologies by using a fuzzy AHP. Wang [53] proposed an environmental performance evaluation model which that consists of AHP, fuzzy extent analysis, and membership degree analysis to evaluate environmental performance of energy usage. Lee et al.[30] presented a conceptual model, which was composed of a fuzzy ANP with interpretive structural modeling and benefits, opportunities, costs and risks, to help analyze suitable strategic products. Lee et al. (2010) proposed integrated fuzzy AHP and data envelopment analysis (DEA) methods for measuring the relative efficiency of the R&D performance in the national hydrogen energy technology development. Kahraman and Kaya [21] presented a fuzzy MCDM methodology for the selection among energy policies. Their methodology was based on the AHP under fuzziness and it allowed the evaluation scores from experts to be linguistic expressions, crisp or fuzzy numbers. They determined the best energy policy for Turkey. Cavallaro [7] aimed to propose test the validity and effectiveness of the proposed fuzzy MCDM

methodology to compare different heat transfer fluids (HTF) in order to investigate the feasibility of utilizing a molten salt. Shen et al. [46]) assessed the 3E goals and renewable energy sources regulated by the Renewable Energy Development Bill that passed in 2009. They used fuzzy AHP to resolve the multi-goal problem for achieving their research purposes. Chen and Pang [9]presented a conceptual model which examined critical characteristics of successful PV solar energy industry in China. They used fuzzy ANP to analyze suitable forms of organization for knowledge management in order to distribute existing knowledge as well as to create new knowledge.. Kahraman et al. [22] proposed an axiomatic design (AD) methodology for the selection among renewable energy alternatives under fuzzy environment to select the most appropriate renewable energy alternative for Turkey. Ruan et al. [41] developed a fuzzy multi-criteria group decision software tool to analyze long-term scenarios for Belgian energy policy.
Unlike these studies, in this paper we used a hybrid MCDM methodology that consists of two MCDM methods with type-2 fuzzy sets for policy making in energy alternatives of Turkey. One of these methods is type-2 fuzzy AHP method is used to determine weights of criteria. The second method is type-2 fuzzy TOPSIS and is used to evaluate the energy alternatives.

1.2. **Energy Sources.** Energy is one of the most basic elements that ensure the continuance of life. Classifications which appear in different forms for different types of energy are available in literature. According to the information obtained from the Ministry of Energy, Turkey is using the energies of wind, solar, hydro, geothermal, biofuel, natural gas, oil and coal. Nuclear and hydrogen energies will be available in the next years. Turkey has as well as a wide range of sources in terms of renewable energy and other types of energy resources. Energy sources are classified according to various criteria. This is one of the criteria of energy resources underground or above ground. According to this classification, underground energy sources are oil, natural gas, coal, and schists. These resources are also referred to as fossil fuels. This group also contains uranium, thorium and geothermal energy resources although it is not fossil fuels. Another classification is examined as primary sources and secondary energy sources obtained as a result of conversion of the of primary energy sources. Petroleum, coal, lignite, hydro, nuclear, geothermal, natural gas, solar, wind, wood, dung and the energy obtained from the sea (tides) are the primary source of energy. Electricity, coke briquettes, coal gas (town gas), biogas, liquefied petroleum gas (LPG) are a secondary energy sources [27]. Another classification is examined as the traditional and alternative sources. Traditional energy sources are based on carbon, oil, coal, natural gas and nuclear. These resources are also known as non-renewable sources of energy which are occurred for many years. Alternative sources are solar, hydrogen, wind, hydro and geothermal energy. These resources are considered as renewable energy sources.

1.3. **Energy Sources for Turkey.** Fossil fuels are mostly used to generate electricity in Turkey. Turkey's primary energy sources are oil, lignite, coal, natural gas, geothermal and hydroelectric energies. Turkey's own energy production meets 48% of all energy needs. Financing requirements for the energy sector in the country

is in high level of the southern and eastern Mediterranean countries [48]. Turkey imports about 70% of energy needs and from this aspect it is a dependent country. According to estimates of the Ministry of Energy, Turkey's energy consumption will be the 222 million tons of oil equivalent (mtoe) annual by 2020. Table 1 shows the potential energy sources in Turkey as of October 2010 [54].

Source	**Reserve / Potential**
Wind	Very Efficient: 8000 MW
	Middle Effective: 40,000 MW
Coal	Lignite: 12.4 billion tons
	Coal: 1.33 million tons
Geothermal	650 MW
Hydro	130 billion kWh / year
Solar	33 mtoe / year
Natural Gas	8 billion m^3
Asphaltite	82 million tons
Oil	43 million tons
Biofuel	8.6 mtoe / year

TABLE 1. Energy Sources of Turkey

Therefore developing of policies which propose effective and efficient use of energy will be useful for Turkey whose energy demand is expected to be higher in the future. In this paper, an analysis is conducted to determine the ranking of energy sources in Turkey. By considering the energy sources used in Turkey, energy alternatives are evaluated from environmental, socio-political, economic, technical and technological aspects and the most appropriate usage of energy alternatives is determined.

2. **The Proposed Methodology**

In this paper, a fuzzy MCDM methodology that consists of AHP and TOPSIS under type-2 fuzzy sets is used to evaluate energy alternatives for Turkey. Type-2 fuzzy AHP is used to obtain weights of criteria and type-2 fuzzy TOPSIS is used to evaluate the alternatives. The type -2 fuzzy AHP that is proposed the first time in this paper is developed to obtain the criteria weights in order to get results closer to reality. Flow chart of the suggested methodology based on type-2 fuzzy sets is shown in Figure 1.

2.1. **The Fuzzy Set Theory.** The linguistic variables used in the evaluation process of criteria and alternatives are turned into digital data with the help of fuzzy logic in decision making problems. For this aim, fuzzy logic used the fuzzy sets, membership functions and fuzzy numbers to convert the uncertain data to the available information. The fuzzy sets define the data with the low, medium, and

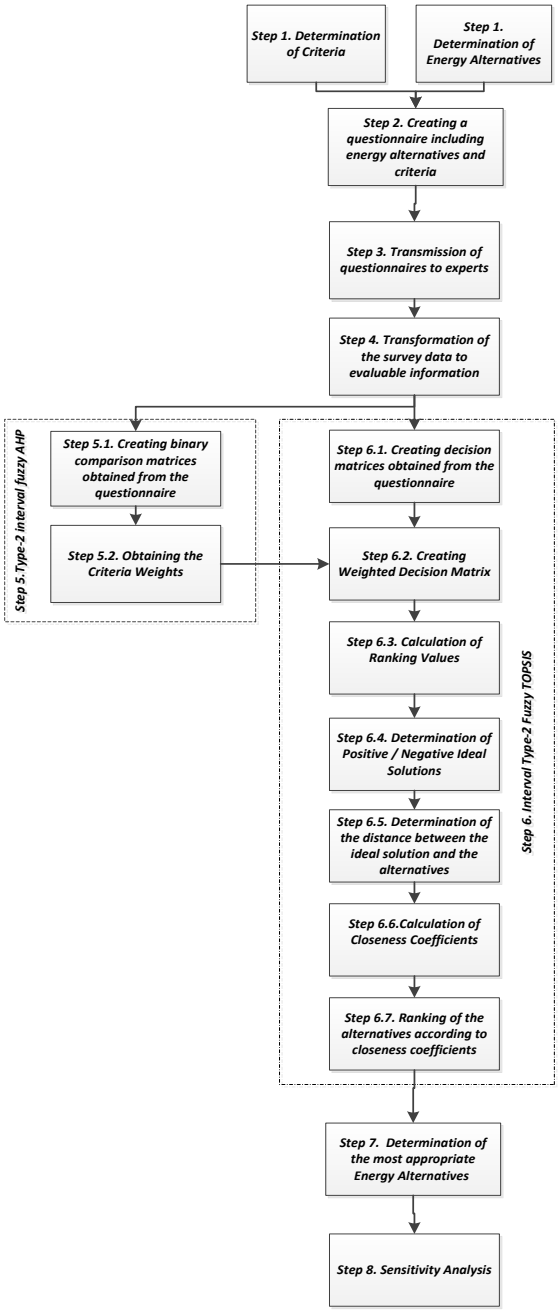


FIGURE 1. The Flowchart of the Suggested Fuzzy MCDM Methodology

maximum limit values that reflect the uncertainty rather than defining them strictly [31]. The fuzzy logic used in decision making problems is examined in two fuzziness level, type-1 and type-2. Following subsections include the general information about type-2 fuzzy sets.

2.1.1. **Type-2 Fuzzy Sets.** The fuzzy set theory introduced by Zadeh [55] is suitable for dealing with the uncertainty and imprecision associated with information concerning various parameters. The concept of type-2 fuzzy sets, as an extension of the concept of the classical fuzzy sets that called type-1 fuzzy sets was introduced by Zadeh [56]. The increasing of fuzziness means the ability of being able to handle imprecise data in the logical means [15]. Type-2 fuzzy sets allow the rating of linguistic memberships [19]. The membership function of type-1 fuzzy sets is crisp numbers. Type-2 fuzzy sets have grades of membership that are themselves fuzzy. Because of the computational complexity of using general type-2 fuzzy sets, interval type-2 fuzzy sets are usually used in practice. Such sets are fuzzy sets whose membership grades themselves are type-1 fuzzy sets; they are very useful in circumstances where it is difficult to determine an exact membership function for a fuzzy set; hence, they are useful for incorporating linguistic uncertainties [25]. Type-2 fuzzy sets are 'fuzzy fuzzy' sets and are more expressive [36]. Type-2 fuzzy sets are described by membership functions that are characterized by more parameters than are membership functions for type-1 fuzzy sets. Hence, type-2 fuzzy sets provide us with more design degrees of freedom; so using type-2 fuzzy sets has the potential to outperform using type-1 fuzzy sets, especially when we are in uncertain environments [35].

2.1.2. **Interval Type-2 Fuzzy Sets.** In this sub-section, some general definitions of type-2 fuzzy sets and interval type-2 fuzzy sets are presented as below [10, 31, 37]:

Definition 2.1. A type-2 fuzzy set $\tilde{\tilde{A}}$ in the universe of discourse X can be represented by a type-2 membership function$\mu_{\tilde{\tilde{A}}}$, shown as follows:

$$\tilde{\tilde{A}} = \left\{ ((x,u), \mu_{\tilde{\tilde{A}}}(x,u)) \,|\forall x \in X, \forall u \in J_X \subseteq [0,1] \,, 0 \leq \mu_{\tilde{\tilde{A}}}(x,u) \leq 1 \right\} \tag{1}$$

Where J_X denotes an interval in $[0,1]$. Moreover, the type-2 fuzzy set $\tilde{\tilde{A}}$ also can be represented as follows:

$$\tilde{\tilde{A}} = \int_{x \in X} \int_{u \in J_X} \mu_{\tilde{\tilde{A}}}(x,u)/(x,u) \tag{2}$$

where $J_X \subseteq [0,1]$and $\iint$denotes union over all admissible x and u.

Definition 2.2. Let $\tilde{\tilde{A}}$be a type-2 fuzzy set in the universe of discourse X represented by the type-2 membership function$\mu_{\tilde{\tilde{A}}}$. If all$\mu_{\tilde{\tilde{A}}}(x,u) = 1$, then $\tilde{\tilde{A}}$ is called an interval type-2 fuzzy set. An interval type-2 fuzzy set $\tilde{\tilde{A}}$ can be regarded as a special case of a type-2 fuzzy set, represented as follows:

$$\tilde{\tilde{A}} = \int_{x \in X} \int_{u \in J_X} 1/(x,u) \tag{3}$$

where $J_X \subseteq [0,1]$

Definition 2.3. The upper membership function and the lower membership function of an interval type-2 fuzzy set are type-1 membership functions, respectively. Figure 2 shows a trapezoidal interval type-2 fuzzy set

$$\tilde{\tilde{A}}_i = \left(\tilde{A}_i^U, \tilde{A}_i^L\right) = \left(\left(a_{i1}^U, a_{i2}^U, a_{i3}^U, a_{i4}^U; H_1\left(\tilde{A}_i^U\right), H_2\left(\tilde{A}_i^U\right)\right), \left(a_{i1}^L, a_{i2}^L, a_{i3}^L, a_{i4}^L; H_1\left(\tilde{A}_i^L\right), H_2\left(\tilde{A}_i^L\right)\right)\right),$$

where $\tilde{A}_i^U$and $\tilde{A}_i^L$are type-1 fuzzy sets, $a_{i1}^U, a_{i2}^U, a_{i3}^U, a_{i4}^U, a_{i1}^L, a_{i2}^L, a_{i3}^L$ and a_{i4}^L are the reference points of the interval type-2 fuzzy $\tilde{\tilde{A}}_i$; $H_j\left(\tilde{A}_i^U\right)$denotes the membership value of the element $a_{i(j+1)}^U$ in the upper trapezoidal membership function $\tilde{A}_i^U$; $1 \le j \le 2$, $H_j\left(\tilde{A}_i^L\right)$denotes the membership value of the element $a_{i(j+1)}^L$ in the lower trapezoidal membership function $\tilde{A}_i^L$; $1 \le j \le 2$, $H_j\left(\tilde{A}_i^L\right)$

$H_1\left(\tilde{A}_i^U\right) \in [0,1]$, $H_2\left(\tilde{A}_i^U\right) \in [0,1]$, $H_1\left(\tilde{A}_i^L\right) \in [0,1]$,$H_2\left(\tilde{A}_i^L\right) \in [0,1]$ and $1 \le i \le n$.

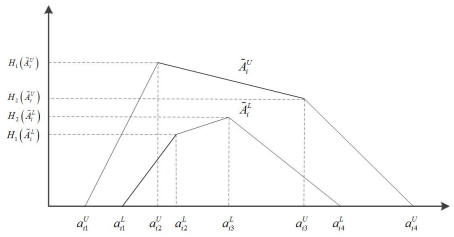


FIGURE 2. The Upper Trapezoidal Membership Function and the Lower Trapezoidal Membership Function of an Interval Type-2 Fuzzy Set

Definition 2.4. The addition operation between two trapezoidal interval type-2 fuzzy sets is defined as follow:

$$\begin{aligned}\tilde{\tilde{A}}_1 &= \left(\tilde{A}_1^U, \tilde{A}_1^L\right)\\ &= \left(\left(a_{11}^U, a_{12}^U, a_{13}^U, a_{14}^U; H_1\left(\tilde{A}_1^U\right), H_2\left(\tilde{A}_1^U\right)\right), \left(a_{11}^L, a_{12}^L, a_{13}^L, a_{14}^L; H_1\left(\tilde{A}_1^L\right), H_2\left(\tilde{A}_1^L\right)\right)\right)\end{aligned} \quad (4)$$

$$\begin{aligned}\tilde{\tilde{A}}_2 &= \left(\tilde{A}_2^U, \tilde{A}_2^L\right)\\ &= \left(\left(a_{21}^U, a_{22}^U, a_{23}^U, a_{24}^U; H_1\left(\tilde{A}_2^U\right), H_2\left(\tilde{A}_2^U\right)\right), \left(a_{21}^L, a_{22}^L, a_{23}^L, a_{24}^L; H_1\left(\tilde{A}_2^L\right), H_2\left(\tilde{A}_2^L\right)\right)\right)\end{aligned} \quad (5)$$

$$\begin{aligned}\tilde{A}_1 \oplus \tilde{A}_2 &= \left(\tilde{A}_1^U, \tilde{A}_1^L\right) \oplus \left(\tilde{A}_2^U, \tilde{A}_2^L\right)\\ &= \left(\begin{array}{l}\left(a_{11}^U + a_{21}^U, a_{12}^U + a_{22}^U, a_{13}^U + a_{23}^U, a_{14}^U + a_{24}^U; \min\left(H_1\left(\tilde{A}_1^U\right), H_1\left(\tilde{A}_2^U\right)\right)\right),\\ \left(a_{11}^L + a_{21}^L, a_{12}^L + a_{22}^L, a_{13}^L + a_{23}^L, a_{14}^L + a_{24}^L; \min\left(H_1\left(\tilde{A}_1^L\right), H_1\left(\tilde{A}_2^L\right)\right)\right),\\ \min\left(H_2\left(\tilde{A}_1^U\right), H_2\left(\tilde{A}_2^U\right)\right),\\ \min\left(H_2\left(\tilde{A}_1^L\right), H_2\left(\tilde{A}_2^L\right)\right)\end{array}\right)\end{aligned} \quad (6)$$

Definition 2.5. The subtraction operation between the trapezoidal interval type-2 fuzzy sets is defined as follow:

$$\tilde{\tilde{A}}_1 = \left(\tilde{A}_1^U, \tilde{A}_1^L\right) = \left(\left(a_{11}^U, a_{12}^U, a_{13}^U, a_{14}^U; H_1\left(\tilde{A}_1^U\right), H_2\left(\tilde{A}_1^U\right)\right), \left(a_{11}^L, a_{12}^L, a_{13}^L, a_{14}^L; H_1\left(\tilde{A}_1^L\right), H_2\left(\tilde{A}_1^L\right)\right)\right) \tag{7}$$

$$\tilde{\tilde{A}}_2 = \left(\tilde{A}_2^U, \tilde{A}_2^L\right) = \left(\left(a_{21}^U, a_{22}^U, a_{23}^U, a_{24}^U; H_1\left(\tilde{A}_2^U\right), H_2\left(\tilde{A}_2^U\right)\right), \left(a_{21}^L, a_{22}^L, a_{23}^L, a_{24}^L; H_1\left(\tilde{A}_2^L\right), H_2\left(\tilde{A}_2^L\right)\right)\right) \tag{8}$$

$$\begin{aligned}\tilde{A}_1 \ominus \tilde{A}_2 &= \left(\tilde{A}_1^U, \tilde{A}_1^L\right) \ominus \left(\tilde{A}_2^U, \tilde{A}_2^L\right) \\ &= \left(\begin{array}{l}\left(a_{11}^U - a_{21}^U, a_{12}^U - a_{22}^U, a_{13}^U - a_{23}^U, a_{14}^U - a_{24}^U; \min\left(H_1\left(\tilde{A}_1^U\right), H_1\left(\tilde{A}_2^U\right)\right)\right), \\ \left(a_{11}^L - a_{21}^L, a_{12}^L - a_{22}^L, a_{13}^L - a_{23}^L, a_{14}^L - a_{24}^L; \min\left(H_1\left(\tilde{A}_1^L\right), H_1\left(\tilde{A}_2^L\right)\right)\right), \\ \min\left(H_2\left(\tilde{A}_1^U\right), H_2\left(\tilde{A}_2^U\right)\right), \\ \min\left(H_2\left(\tilde{A}_1^L\right), H_2\left(\tilde{A}_2^L\right)\right)\end{array}\right)\end{aligned} \tag{9}$$

Definition 2.6. The multiplication operation between the trapezoidal interval type-2 fuzzy sets is defined as follow:

$$\tilde{\tilde{A}}_1 = \left(\tilde{A}_1^U, \tilde{A}_1^L\right) = \left(\left(a_{11}^U, a_{12}^U, a_{13}^U, a_{14}^U; H_1\left(\tilde{A}_1^U\right), H_2\left(\tilde{A}_1^U\right)\right), \left(a_{11}^L, a_{12}^L, a_{13}^L, a_{14}^L; H_1\left(\tilde{A}_1^L\right), H_2\left(\tilde{A}_1^L\right)\right)\right) \tag{10}$$

$$\tilde{\tilde{A}}_2 = \left(\tilde{A}_2^U, \tilde{A}_2^L\right) = \left(\left(a_{21}^U, a_{22}^U, a_{23}^U, a_{24}^U; H_1\left(\tilde{A}_2^U\right), H_2\left(\tilde{A}_2^U\right)\right), \left(a_{21}^L, a_{22}^L, a_{23}^L, a_{24}^L; H_1\left(\tilde{A}_2^L\right), H_2\left(\tilde{A}_2^L\right)\right)\right) \tag{11}$$

$$\begin{aligned}\tilde{A}_1 \otimes \tilde{A}_2 &= \left(\tilde{A}_1^U, \tilde{A}_1^L\right) \otimes \left(\tilde{A}_2^U, \tilde{A}_2^L\right) \\ &= \left(\begin{array}{l}\left(a_{11}^U \times a_{21}^U, a_{12}^U \times a_{22}^U, a_{13}^U \times a_{23}^U, a_{14}^U \times a_{24}^U; \min\left(H_1\left(\tilde{A}_1^U\right), H_1\left(\tilde{A}_2^U\right)\right)\right), \\ \left(a_{11}^L \times a_{21}^L, a_{12}^L \times a_{22}^L, a_{13}^L \times a_{23}^L, a_{14}^L \times a_{24}^L; \min\left(H_1\left(\tilde{A}_1^L\right), H_1\left(\tilde{A}_2^L\right)\right)\right), \\ \min\left(H_2\left(\tilde{A}_1^U\right), H_2\left(\tilde{A}_2^U\right)\right), \\ \min\left(H_2\left(\tilde{A}_1^L\right), H_2\left(\tilde{A}_2^L\right)\right)\end{array}\right)\end{aligned} \tag{12}$$

Definition 2.7. Some arithmetic operations between the trapezoidal interval type-2 fuzzy sets are defined as follow:

$$\tilde{\tilde{A}}_1 = \left(\tilde{A}_1^U, \tilde{A}_1^L\right) = \left(\left(a_{11}^U, a_{12}^U, a_{13}^U, a_{14}^U; H_1\left(\tilde{A}_1^U\right), H_2\left(\tilde{A}_1^U\right)\right), \left(a_{11}^L, a_{12}^L, a_{13}^L, a_{14}^L; H_1\left(\tilde{A}_1^L\right), H_2\left(\tilde{A}_1^L\right)\right)\right) \tag{13}$$

$$k\tilde{\tilde{A}}_1 = \left(\begin{array}{l}\left(k \times a_{11}^U, k \times a_{12}^U, k \times a_{13}^U, k \times a_{14}^U; H_1\left(\tilde{A}_1^U\right), H_2\left(\tilde{A}_1^U\right)\right), \\ \left(k \times a_{11}^L, k \times a_{12}^L, k \times a_{13}^L, k \times a_{14}^L; H_1\left(\tilde{A}_1^L\right), H_2\left(\tilde{A}_1^L\right)\right)\end{array}\right) \tag{14}$$

$$\frac{\tilde{\tilde{A}}_1}{k} = \left(\begin{array}{l}\left(\frac{1}{k} \times a_{11}^U, \frac{1}{k} \times a_{12}^U, \frac{1}{k} \times a_{13}^U, \frac{1}{k} \times a_{14}^U; H_1\left(\tilde{A}_1^U\right), H_2\left(\tilde{A}_1^U\right)\right), \\ \left(\frac{1}{k} \times a_{11}^L, \frac{1}{k} \times a_{12}^L, \frac{1}{k} \times a_{13}^L, \frac{1}{k} \times a_{14}^L; H_1\left(\tilde{A}_1^L\right), H_2\left(\tilde{A}_1^L\right)\right)\end{array}\right) \tag{15}$$

Definition 2.8. The ranking value $Rank(\tilde{\tilde{A}}_i)$ of the trapezoidal interval type-2 fuzzy set $\tilde{\tilde{A}}_i$is defined as follows:

$$\begin{aligned} Rank(\tilde{\tilde{A}}_i) = {} & M_1\left(\tilde{A}_i^U\right) + M_1\left(\tilde{A}_i^L\right) + M_2\left(\tilde{A}_i^U\right) + M_2\left(\tilde{A}_i^L\right) \\ & + M_3\left(\tilde{A}_i^U\right) + M_3\left(\tilde{A}_i^L\right) - \frac{1}{4}\left(S_1\left(\tilde{A}_i^U\right) + S_1\left(\tilde{A}_i^L\right)\right. \\ & + S_2\left(\tilde{A}_i^U\right) + S_2\left(\tilde{A}_i^L\right) + S_3\left(\tilde{A}_i^U\right) + S_3\left(\tilde{A}_i^L\right) + S_4\left(\tilde{A}_i^U\right) \\ & \left. + S_4\left(\tilde{A}_i^L\right)\right) + H_1\left(\tilde{A}_i^U\right) + H_1\left(\tilde{A}_i^L\right) + H_2\left(\tilde{A}_i^U\right) + H_2\left(\tilde{A}_i^L\right) \quad (16) \end{aligned}$$

where $M_p(\tilde{\tilde{A}}_i^j)$denotes the average of the elements a_{ip}^j and $a_{i(p+1)}^j$,

$$M_p(\tilde{\tilde{A}}_i^j) = \left(a_{ip}^j + a_{i(p+1)}^j\right)/2, 1 \le p \le 3,$$

denotes the standard deviation of the elements a_{iq}^j and $a_{i(q+1)}^j$,

$$S_q(\tilde{A}_i^j) = \sqrt{\frac{1}{2}\sum_{k=q}^{q+1}\left(a_{ik}^j - \frac{1}{2}\sum_{k=q}^{q+1} a_{ik}^j\right)^2}\ ,\ 1 \le q \le 3,$$

$S_4(\tilde{A}_i^j)$ denotes the standard deviation of the elements $a_{i1}^j, a_{i2}^j, a_{i3}^j, a_{i4}^j$,

$$S_4(\tilde{A}_i^j) = \sqrt{\frac{1}{4}\sum_{k=1}^{4}\left(a_{ik}^j - \frac{1}{4}\sum_{k=1}^{4} a_{ik}^j\right)^2}$$

$H_p(\tilde{A}_i^j)$ denotes the membership value of the element $a_{i(p+1)}^j$ in the trapezoidal membership function $\tilde{A}_i^j, 1 \le p \le 3, j \in \{U, L\}$, and $1 \le i \le n$.

2.2. **Interval Type -2 Fuzzy AHP.** Analytical Hierarchy Process (AHP) that is very useful technique in solving problems involving quantitative and qualitative criteria is a MCDM method which developed by Thomas L. Saaty [43]. Laarhoven and Pedrycz [52] provided the use of the method for the situations that involve uncertainty by combining AHP with fuzzy logic. Buckley [6] has worked on the fuzzy comparison rates with expanding method. The geometric mean method was used in order to obtain fuzzy weights and performance scores in his proposed method by Buckley. The reason for using this method was to easily generalize fuzzy situations and guarantee to obtain a single solution from comparison matrices. Buckley also used fuzzy trapezoidal numbers instead of triangular fuzzy numbers (zgn, 2006). In this paper, to better reflect the uncertainties for determining the criteria weights, interval type-2 fuzzy AHP is suggested. The AHP method proposed by Buckley is developed in the framework of interval type-2 fuzzy sets in the first time in this paper. The steps of proposed type-2 fuzzy AHP method are as follows:

Step 1: Decision hierarchy of criteria and alternatives is created.

Step 2: Scale used to evaluate the criteria is determined. The scale that is used to convert to linguistic terms into interval type-2 fuzzy sets for this paper is shown in Table 2. The membership function of this scale is shown in Figure 3.

Linguistic Terms	*Interval Type-2 Fuzzy Corresponding*
Equal	(1, 1, 1, 1; 1, 1),(1, 1, 1, 1; 0.85, 0.85)
More Important	(1, 2, 4, 5; 1, 1),(1.1, 2.1, 3.9, 4.9; 0.85, 0.85)
Very Important	(3, 4, 6, 7; 1, 1),(3.1, 4.1, 5.9, 6.9; 0.85, 0.85)
Very Strong Important	(5, 6, 8, 9; 1, 1),(5.1, 6.1, 7.9, 8.9; 0.85, 0.85)
Absolutely Important	(7, 8, 9, 9; 1, 1),(7.1, 8.1, 8.9, 8.9; 0.85, 0.85)

TABLE 2. Linguistic Scale for Interval Type-2 Fuzzy Numbers

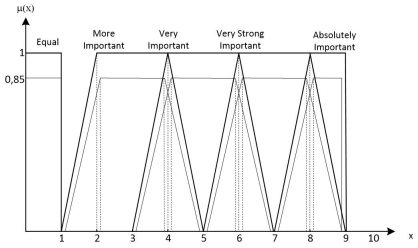


FIGURE 3. The Membership Function of Linguistic Scale

Step 3: Pairwise comparison matrices in the hierarchy are created for all criteria. Fuzzy pairwise comparison matrix can be created as follows:

$$\tilde{\tilde{\mathrm{A}}} = \begin{bmatrix} 1 & \tilde{\tilde{a}}12 & ... & .... & \tilde{\tilde{a}}1m \\ \tilde{\tilde{a}}21 & 1 & ... & ... & \tilde{\tilde{a}}2m \\ : & : & ... & ... & : \\ : & : & ... & ... & : \\ \tilde{\tilde{a}}1n & \tilde{\tilde{a}}2n & ... & ... & 1 \end{bmatrix} \tag{17}$$

$$\tilde{\tilde{a}}ij = \frac{1}{\tilde{\tilde{a}}ji} \tag{18}$$

for example; $\tilde{\tilde{a}}31 = \frac{1}{\tilde{\tilde{a}}13}$

$$\tilde{\tilde{a}} = ((a_{11}^U; a_{12}^U; a_{13}^U; a_{14}^U; H_1(a^U); H2(a^U), (a_{11}^L; a_{12}^L; a_{13}^L; a_{14}^L; H_1(a^L); H2(a^L)) \tag{19}$$

So,

$$\frac{1}{\tilde{\tilde{a}}} = ((\frac{1}{a_{14}^U}; \frac{1}{a_{13}^U}; \frac{1}{a_{12}^U}; \frac{1}{a_{11}^U}; H_1(a_{12}^U); H2(a_{13}^U), (\frac{1}{a_{14}^L}; \frac{1}{a_{13}^L}; \frac{1}{a_{12}^L}; \frac{1}{a_{11}^L}; H_1(a_{12}^L); H2(a_{13}^L)) \tag{20}$$

Step 4: Defuzzification is applied for all of the comparison matrices and consistency index is calculated. Saaty [42] used consistency ratios using the principal eigenvector of a positive pairwise comparison matrix. Consistency ratio is calculated by using the following formulas. If the consistency index (CI) is smaller than 0.1, the pairwise comparison matrices are consistent.

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{21}$$

$$CR = \frac{CI}{RI} \tag{22}$$

"n" is the is the number of criteria and RI is the random index that is related with number of criteria

Step 5: The geometric mean of each criterion is calculated.

$$\tilde{\tilde{r}}i = [\tilde{\tilde{a}}_{i1} \otimes \tilde{\tilde{a}}_{i2} \otimes ... \otimes \tilde{\tilde{a}}_{im}]^{1/n} \tag{23}$$

$$\begin{aligned}(\tilde{\tilde{a}}ij)^{1/n} = ((\tilde{\tilde{a}}^U_{i1})^{1/n}; (\tilde{\tilde{a}}^U_{i2})^{1/n}; (\tilde{\tilde{a}}^U_{i3})^{1/n}; (\tilde{\tilde{a}}^U_{i4})^{1/n}; H_1(a^U_{i2}); H_2(a^U_{i3}),\\ (\tilde{\tilde{a}}^L_{i1})^{1/n}; (\tilde{\tilde{a}}^L_{i2})^{1/n}; (\tilde{\tilde{a}}^L_{i3})^{1/n}; (\tilde{\tilde{a}}^L_{i4})^{1/n}; H_1(a^L_{i2}); H_2(a^L_{i3}))\end{aligned} \tag{24}$$

Step 6: The criteria weights are calculated with normalization process

$$wi = \tilde{\tilde{r}}i = [\tilde{\tilde{r}}1 \oplus \tilde{\tilde{r}}2 \oplus ... \oplus \tilde{\tilde{r}}n]^{-1} \tag{25}$$

Step 7: Defuzzify the fuzzy numbers for determining the degree of importance of criteria**.**

2.3. **Interval Type-2 Fuzzy TOPSIS.** In the following, the TOPSIS method has been extended to present a new method for handling fuzzy multiple attributes group decision-making problems based on interval type-2 fuzzy sets. Assume that there is a set X of alternatives, where $X = \{x1, x2, ..., xn\}$, and assume that there is a set F of attributes, where $F = \{f1, f2, ..., fm\}$. Assume that there are k decision-makers D_1, $D_2 \ldots$ and D_k. The set F of attributes can be divided into two sets F_1 and F_2, where F_1 denotes the set of benefit attributes, F_2 denotes the set of cost attributes, $F1 \cap F2 = \phi$, and $F1 \cup F2 = F$. The proposed interval type-2 fuzzy TOPSIS method can be presented as follows [31]:

Step 1: Construct the decision matrix Y_p of the p^{th} decision-maker and construct the average decision matrix $\bar{Y}$, respectively, shown as follows:

$$Yp = (\tilde{f}^p_{ij})mxn = \begin{array}{c} \\ f1 \\ f2 \\ : \\ : \\ fm \end{array} \begin{array}{c} \begin{array}{ccccccc} x1 & x2 & x3 & ..... & xn & & \end{array} \\ \begin{bmatrix} \tilde{\tilde{f}}^p_{11} & \tilde{\tilde{f}}^p_{12} & \tilde{\tilde{f}}^p_{13} & .... & \tilde{\tilde{f}}^p_{1n} \\ \tilde{\tilde{f}}^p_{21} & \tilde{\tilde{f}}^p_{21} & ... & ... & \tilde{\tilde{f}}^p_{2n} \\ : & : & ... & ... & \\ : & : & ... & ... & \\ \tilde{\tilde{f}}^p_{m1} & \tilde{\tilde{f}}^p_{m2} & & & \tilde{\tilde{f}}^p_{mn} \end{bmatrix} \end{array} \tag{26}$$

$$\bar{Y} = (\tilde{\tilde{f}}^p_{ij})\, mxn, \tag{27}$$

where $\tilde{\tilde{f}}ij = \left(\frac{\tilde{\tilde{f}}_{ij}^{1} \oplus \tilde{\tilde{f}}_{ij}^{2} \ldots \oplus \tilde{\tilde{f}}_{ij}^{k}}{k}\right)$, $\tilde{\tilde{f}}ij$ is an interval type-2 fuzzy set, $1 \leqslant i \leqslant m$, $1 \leqslant j \leqslant, n$, $1 \leqslant p \leqslant k$, and k denote s the number of decision-makers.
The scale used in the scoring of alternatives and criteria are shown in Table 3.

Linguistic Terms	*Interval Type-2 Corresponding*
Very Low	(0, 0, 0, 0.1; 1, 1),(0, 0, 0, 0.05; 0.9, 0.9)
Low	(0, 0.1, 0.1, 0.3; 1, 1),(0.05, 0.1, 0.1, 0.2; 0.9, 0.9)
Medium Low	(0.1, 0.3, 0.3, 0.5; 1, 1),(0.2, 0.3, 0.3, 0.4; 0.9, 0.9)
Medium	(0.3, 0.5, 0.5, 0.7; 1, 1),(0.4, 0.5, 0.5, 0.6; 0.9, 0.9)
Medium High	(0.5, 0.7, 0.7, 0.9; 1, 1),(0.6, 0.7, 0.7, 0.8; 0.9, 0.9)
High	(0.7, 0.9, 0.9, 0.9; 1, 1),(0.8, 0.9, 0.9, 0.95; 0.9, 0.9)
Very High	(0.9, 1, 1, 1; 1, 1),(0.95, 1, 1, 1; 0.9, 0.9)

TABLE 3. Linguistic Scale for Interval Type-2 Fuzzy Numbers

Step 2: Construct the weighting matrix W_p of the attributes of the p^{th} decision-maker and construct the average weighting matrix $\bar{W}$, respectively, shown as follows:

$$Wp = (\tilde{\tilde{w}}_i^p)1xm = \begin{bmatrix} f1 & f1 & & fm \\ \tilde{\tilde{w}}_1^p & \tilde{\tilde{w}}_1^p & \ldots & \tilde{\tilde{w}}_n^p \end{bmatrix}, \tag{28}$$

$$\bar{W} = (\tilde{\tilde{w}}_i)1xm, \tag{29}$$

$\tilde{\tilde{w}}_i = \frac{\tilde{\tilde{w}}_i^1 \oplus \tilde{\tilde{w}}_i^2 \oplus \ldots \oplus \tilde{\tilde{w}}_i^k}{k}$, $\tilde{\tilde{w}}_i$ is an interval type-2 fuzzy set, $1 \leqslant i \leqslant m, 1 \leqslant p \leqslant k$, and k denotes the number of decision makers.

Step 3: Construct the weighted decision matrix$\bar{Y}w$,

$$\bar{Y}w = (\tilde{\tilde{v}}_{ij})mxn = \begin{array}{c} \\ f1 \\ f2 \\ : \\ : \\ fm \end{array} \begin{array}{c} \begin{array}{ccccc} x1 & x2 & x3 & ..... & xn \end{array} \\ \begin{bmatrix} \tilde{\tilde{v}}_{11} & \tilde{\tilde{v}}_{12} & \tilde{\tilde{v}}_{13} & .... & \tilde{\tilde{v}}_{1n} \\ \tilde{\tilde{v}}_{21} & \tilde{\tilde{v}}_{22} & \ldots & \ldots & \tilde{\tilde{v}}_{2n} \\ : & : & \ldots & \ldots & \\ : & : & \ldots & \ldots & \\ \tilde{\tilde{v}}_{m1} & \tilde{\tilde{v}}_{m1} & & & \tilde{\tilde{v}}_{m1} \end{bmatrix} \end{array}, \tag{30}$$

Step 4: Based on equation (16), calculate the ranking value $Rank(\tilde{\tilde{v}}_{ij})$ of the interval type-2 fuzzy set $\tilde{\tilde{v}}_{ij}$, where $1 \leqslant j \leqslant n$. Construct the ranking weighted decision

matrix $\bar{Y}_w^*$,

$$\bar{Y}_w^* = (Rank(\tilde{\tilde{v}}_{ij}))mxn, \tag{31}$$

where $1 \leqslant i \leqslant m$ and $1 \leqslant j \leqslant n$.

Step 5: Determine the positive ideal solution $x^+ = (v_1^+, v_2^+, ..., v_m^+)$ and the negative-ideal solution $x^- = (v_1^-, v_2^-, ..., v_m^-)$,where

$$v_i^+ = \begin{cases} \max\limits_{1\leq j\leq n} \{Rank(\tilde{\tilde{v}}_{ij})\}, & \text{if fi} \in F1 \\ \min\limits_{1\leq j\leq n} \{Rank(\tilde{\tilde{v}}_{ij})\}, & \text{if fi} \in F2 \end{cases} \tag{32}$$

and

$$v_i^- = \begin{cases} \min\limits_{1\leq j\leq n} \{Rank(\tilde{\tilde{v}}_{ij})\}, & \text{if fi} \in F1 \\ \max\limits_{1\leq j\leq n} \{Rank(\tilde{\tilde{v}}_{ij})\}, & \text{if fi} \in F2 \end{cases} \tag{33}$$

where F_1 denotes the set of benefit attributes, F_2 denotes the set of cost attributes, and $1 \leqslant i \leqslant m$.

Step 6: Calculate the distance $d^+(xj)$ between each alternative xj and the positive ideal solution x^+, shown as follows:

$$d^+(xj) = \sqrt{\sum_{i=1}^{m} (Rank(\tilde{\tilde{v}}_{ij}) - v_i^+)^2}, \tag{34}$$

where $1 \leqslant j \leqslant n$. Calculate the distance $d^-(xj)$ between each alternative xj and the negative-ideal solution x^-, shown as follows:

$$d^-(xj) = \sqrt{\sum_{i=1}^{m} (Rank(\tilde{\tilde{v}}_{ij}) - v_i^-)^2}, \tag{35}$$

where $1 \leqslant j \leqslant n$.

Step 7: Calculate the relative degree of closeness $C(xj)$ of xj with respect to the positive ideal solution x^+, shown as follows:

$$C(xj) = \frac{d^-(xj)}{d^-(xj) + d^+(xj)}, \tag{36}$$

where $1 \leqslant j \leqslant n$.

Step 8: Sort the values of $C(xj)$ in a descending sequence, where $1 \leqslant j \leqslant n$. The larger the value of $C(xj)$ means the higher the preference of the alternative xj, where $1 \leqslant j \leqslant n$.

3. **A Real Case Study for Turkey**

Energy production, consumption and determining the best policy are indicators of economic and social development. The amount of energy consumed in developing country is increasing day by day. In Turkey, the amount of electricity consumed per capita reached 3,099 kWh. Table 4 shows the amount of energy consumed per person annually for the whole world and our country [50].

Country	*Consumption per Person*
World Average	2500
Developed Country Average	8900
USA	12322
Turkey	3099

TABLE 4. Electricity Consumption Per Person Annually

As energy consumption is a natural need and adopting it as a common requirement of society, the energy policies which target to benefit from local and renewable energy sources in maximum extent should be developed [51]. In this paper, we aimed to obtain a ranking for energy alternatives of Turkey. Thus, we aimed to contribute to determine the most appropriate energy policy that is conducting in Turkey. The criteria are determined with respect to relevant literature and experts' ideas. The evaluated energy alternatives are determined based on energy sources used in Turkey by Ministry of Energy and Natural Resources (Turkish Republic Ministry of Energy and Natural Resources, 2013). The energy alternatives are determined as coal, oil, natural gas, solar, wind, geothermal, biomass and hydro energy. The energy alternatives are evaluated with respect to the main criteria and sub-criteria. These criteria and the papers that utilized to determine these criteria are shown in the Table 5.

Figure 4 shows hierarchical structure of energy decision making problem.

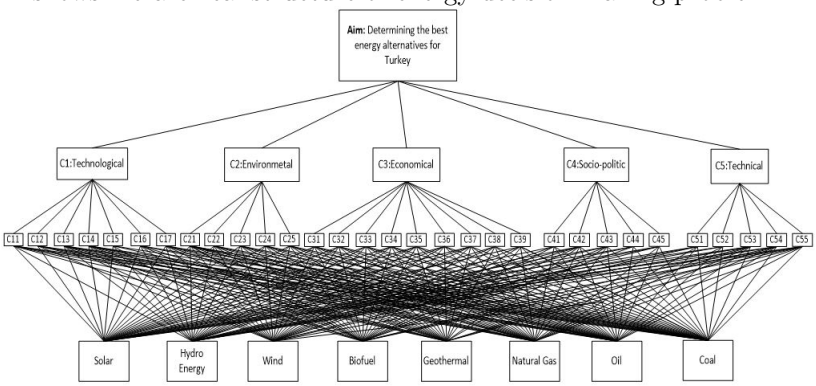


FIGURE 4. The Hierarchical Structure for Energy Decision Making Problem

In the first stage, weights of the criteria have been obtained as a result of evaluations of the experts by using type-2 fuzzy AHP. For this aim, a questionnaire is used to obtain experts' scores about criteria. After obtaining criteria comparisons, it is examined whether the comparison matrices are consistent or not.

Table 6 shows the consistency ratios for pair wise comparison matrices.

After consistency ratios have been calculated, the weights of criteria are obtained by using interval type-2 fuzzy AHP method. Table 7 shows the weights of criteria. Then the interval type-2 fuzzy TOPSIS method is used to evaluate energy alternatives. The weighted decision matrix is obtained as shown in Table 8.

The positive and negative ideal solutions are created by considering ranking values. Then the distances to the ideal solutions of each alternative are calculated. According to this index, called closeness coefficient index, the ranking of alternatives is obtained as shown in Table 9.

Main Criteria	*Sub-Criteria*	*Literature*
C1:Tecnologic	C11:Feasibility	(Kahraman and Kaya,2010)
	C12:Risk	(Kahraman and Kaya,2010; Ulutaş, 2005; Ruan et al.,2010)
	C13:Reliability	(Kahraman and Kaya,2010; Kaya and Kahraman,2011; Erol and Kılkış,2012)
	C14:The duration of preparation phase	(Kahraman and Kaya,2010)
	C15:The duration of implementation phase	(Kahraman and Kaya,2010)
	C16:Continuity and predictability of performance	(Kahraman and Kaya,2010)
	C17:Local technical know how	(Ruan et al.,2010; Kahraman and Kaya,2010)
C2:Environmental	C21: Pollutant emission/Impact on natural ecosystems(NOx ,S02,CO,CO2, partide emission)/Carbon Footprint	(Wang et al., 2010; Ruan et al.,2010; Kahraman and Kaya,2010; Kaya and Kahraman,2011)
	C22:Land Requirement	(Ruan et al., 2010; Kahraman and Kaya,2010; Kaya and Kahraman,2011)
	C23:Need of waste disposal	(Kahraman and Kaya,2010)
	C24:Water pollution	(Wang et al.,2010)
	C25:Land disruption	(Wang et al.,2010)
C3:Economic	C31Running/Implementation/Maintenance cost	(Ulutaş, 2005; Kahraman and Kaya,2010; Kaya and Kahraman,2011)
	C32:Investment cost	(Kaya and Kahraman, 2011)
	C33:Economic value	(Kahraman and Kaya,2010)
	C34:Service life	(Kaya and Kahraman,2011)
	C35:Local and regional economic development	(Karakosta et al., 2009)
	C36:Economic risks	(Ruan et al., 2010)
	C37:Security of energy supply	(Ruan et al., 2010)
	C38:The sustainability of the energy resources	(Topçu and Ülengin,2004; Erol and Kılkış, 2012)
	C39: Source durability	(Erol and Kılkış, 2012)
C4:Socio-political	C41:Compatibility with the national energy policy objectives	(Kahraman and Kaya,2010)
	C42:Political acceptance	(Kahraman and Kaya,2010)
	C43: Social acceptance	(Kahraman and Kaya,2010; Kaya and Kahraman,2011)
	C44:Labour impact	(Kahraman and Kaya,2010)
	C45:Job creation potantial	(Wang et al., 2010; Kaya and Kahraman, 2011)
C5:Technical	C51: Efficiency	(Kaya and Kahraman,2011)
	C52:Exergy efficiency	(Kaya and Kahraman,2011)
	C53:Reliability of Technology and Operation	(Erol and Kılkış, 2012)
	C54:Technology Maturity	(Wang, 2010; Kaya and Kahraman, 2011)
	C55:Ease of Access to the Source	(Erol and Kılkış, 2012)

TABLE 5. The Criteria with Relevant Literature

	Consistency Ratios		
Matrices	*Expert-1*	*Expert-2*	*Expert-3*
The matrix of the main criteria	0.0881	0.072515	0.07697
Sub Criteria Matrix for Technologic Criteria	0.072373	0.08189	0.092378
Sub Criteria Matrix for Environmental Criteria	0.037339	0.092031	0.079054
Sub Criteria Matrix for Economical Criteria	0.074815	0.054359	0.079951
Sub Criteria Matrix for Socio-Politic Criteria	0.075932	0.083426	0.083781
Sub Criteria Matrix for Technical Criteria	0.093085	0.070907	0.060859

TABLE 6. The Results of Consistency Analysis

Criteria	*Weight*
Technological	*(0.04,0.05,0.09,0.14,1,1),(0.04,0.06,0.07,0.14,0.85,0.85)*
Feasibility	*(0,0.01,0.02,0.05,1,1),(0,0.01,0.02,0.04,0.85,0.85)*
Risk	*(0,0,0.01,0.02,1,1),(0,0,0.01,0.02,0.85,0.85)*
Reliability	*(0,0.01,0.02,0.03,1,1),(0,0.01,0.01,0.03,0.85,0.85)*
The duration of preparation phase	*(0,0,0.01,0.03,1,1),(0,0.01,0.01,0.03,0.85,0.85)*
The duration of implementation phase	*(0,0,0.01,0.02,1,1),(0,0,0.01,0.02,0.85,0.85)*
Continuity and predictability of performance	*(0,0.01,0.02,0.04,1,1),(0,0.01,0.02,0.04,0.85,0.85)*
Local technical know how	*(0,0,0.01,0.03,1,1),(0,0.01,0.01,0.03,0.85,0.85)*
Environmental	*(0.11,0.14,0.22,0.31,1,1),(0.11,0.18,0.17,0.3,0.85,0.85)*
Pollutant emission/impact on natural ecosystems (NOx ,SO2,CO,CO2,particle emission/Carbon Footprint	*(0.01,0.01,0.04,0.08,1,1),(0.01,0.02,0.03,0.07,0.85,0.85)*
Land Requirement	*(0,0.01,0.01,0.03,1,1),(0,0.01,0.01,0.03,0.85,0.85)*
Need of waste disposal	*(0.01,0.02,0.05,0.1,1,1),(0.01,0.03,0.04,0.09,0.85,0.85)*
Water pollution	*(0.02,0.03,0.07,0.14,1,1),(0.02,0.04,0.06,0.13,0.85,0.85)*
Land disruption	*(0.02,0.04,0.1,0.19,1,1),(0.02,0.05,0.08,0.17,0.85,0.85)*
Economical	*(0.16,0.22,0.34,0.43,1,1),(0.17,0.28,0.27,0.42,0.85,0.85)*
Running/implementation/Maintenance cost	*(0,0.01,0.02,0.05,1,1),(0.01,0.01,0.02,0.04,0.85,0.85)*
Investment cost	*(0,0.01,0.02,0.05,1,1),(0.01,0.01,0.02,0.04,0.85,0.85)*
Economic value	*(0.01,0.01,0.03,0.05,1,1),(0.01,0.01,0.02,0.05,0.85,0.85)*
Service life	*(0.01,0.01,0.03,0.07,1,1),(0.01,0.02,0.02,0.06,0.85,0.85)*
Local and regional economic development	*(0.02,0.03,0.08,0.13,1,1),(0.02,0.04,0.06,0.12,0.85,0.85)*
Economic risks	*(0.01,0.02,0.05,0.08,1,1),(0.01,0.02,0.04,0.08,0.85,0.85)*
Security of energy supply	*(0.01,0.03,0.08,0.14,1,1),(0.01,0.04,0.06,0.13,0.85,0.85)*
The sustainability of the energy resources	*(0.02,0.03,0.08,0.13,1,1),(0.02,0.04,0.06,0.12,0.85,0.85)*
Source durability	*(0.01,0.02,0.05,0.09,1,1),(0.01,0.03,0.04,0.08,0.85,0.85)*
Socio-politic	*(0.13,0.19,0.31,0.42,1,1),(0.14,0.24,0.25,0.42,0.85,0.85)*
Compatibility with the national energy policy objective	*(0.01,0.02,0.05,0.09,1,1),(0.01,0.02,0.04,0.09,0.85,0.85)*
Political acceptance	*(0.01,0.02,0.05,0.1,1,1),(0.01,0.02,0.04,0.1,0.85,0.85)*
Social acceptance	*(0.03,0.07,0.23,0.42,1,1),(0.04,0.09,0.17,0.41,0.85,0.85)*
Labour impact	*(0.01,0.02,0.05,0.09,1,1),(0.01,0.02,0.04,0.09,0.85,0.85)*
Job creation potential	*(0.01,0.02,0.04,0.07,1,1),(0.01,0.02,0.03,0.07,0.85,0.85)*
Technical	*(0.13,0.19,0.31,0.42,1,1),(0.14,0.24,0.25,0.41,0.85,0.85)*
Efficiency	(0.01,0.01,0.04,0.08,1,1),(0.01,0.02,0.03,0.08,0.85,0.85)
Exergy efficiency	(0.02,0.05,0.13,0.23,1,1),(0.03,0.06,0.1,0.22,0.85,0.85)
Reliability of Technology and Operation	(0.02,0.03,0.08,0.15,1,1),(0.02,0.04,0.06,0.14,0.85,0.85)
Technology Maturity	(0.01,0.01,0.03,0.07,1,1),(0.01,0.01,0.02,0.06,0.85,0.85)
Ease of Access to the Source	(0.02,0.05,0.13,0.23,1,1),(0.02,0.06,0.1,0.21,0.85,0.85)

TABLE 7. The Weights of Criteria

	Solar Energy	Hydro energy	Wind Energy	Biofuel Energy
C11	(0,0.01,0.02,0.04,1.1),(0,0.01,0.01,0.04,0.85,0.85)	(0,0.01,0.02,0.04,1,1),(0,0.01,0.01,0.04,0.85,0.85)	(0,0.01,0.02.0.05,1,1),(0,0.01,0.02,0.04,0.85,0.85)	(0,0,0.01,0.02,1,1),(0,0,0,0.01,0.85,0.85)
C12	(0,0,0,0.01,1.1),(),(0,0,0,0.85,0.85)	(0,0,0,0,1,1),(0,0,0,0,0.85,0.85)	(0,0,0.0.01,1,1),(0,0,0,0.85,0.85)	(0,0,0,0.01,1,1),(0,0,0,0.01,0.85,0.85)
C13	(0,0.01,0.01,0.03,1.1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0,0.01,0.03,1,1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0.01,0.01.0.03,1,1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0.01,0.02,0.03,1,1),(0,0.01,0.01,0.03,0.85,0.85)
C14	(0,0,0.01,0.03,1.1),(0,0,0.01,0.02,0.85,0.85)	(0,0,0.01,0.03,1,1),(0,0,0.01,0.02,0.85,0.85)	(0,0,0.01.0.02,1,1),(0,0,0.01,0.02,0.85,0.85)	(0,0,0.01,0.03,1,1),(0,0.01,0.01,0.03,0.85,0.85)
C15	(0,0,0.01,0.02,1.1),(0,0,0,0.02,0.85,0.85)	(0,0,0,0.01,1,1),(0,0,0,0.01,0.85,0.85)	(0,0,0.01.0.02,1,1),(0,0,0.01,0.02,0.85,0.85)	(0,0,0.01,0.02,1,1),(0,0,0,0.02,0.85,0.85)
C16	(0,0.01,0.02,0.04,1.1),(0,0.01,0.01,0.04,0.85,0.85)	(0,0.01,0.02,0.04,1,1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0.01,0.01.0.04,1,1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0,0.01,0.03,1,1),(0,0.01,0.01,0.03,0.85,0.85)
C17	(0,0,0.01,0.02,1.1),(0,0,0,0.02,0.85,0.85)	(0,0,0.01,0.02,1,1),(0,0,0,0.02,0.85,0.85)	(0,0,0.01.0.02,1,1),(0,0,0.01,0.02,0.85,0.85)	(0,0,0.01,0.03,1,1),(0,0.01,0.01,0.02,0.85,0.85)
C21	(0.01,0.01,0.03,0.08,1.1),(0.01,0.02,0.03,0.07,0.85,0.85)	(0,0,0.01,0.03,1,1),(0,0,0.01,0.02,0.85,0.85)	(0.01,0.01,0.03.0.08,1,1),(0.01,0.02,0.03,0.07,0.85,0.85)	(0.01,0.01,0.03,0.08,1,1),(0.01,0.02,0.02,0.07,0.85,0.85)
C22	(0,0.01,0.01,0.03,1.1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0.01,0.01,0.03,1,1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0.01,0.01.0.03,1,1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0.01,0.01,0.03,1,1),(0,0.01,0.01,0.03,0.85,0.85)
C23	(0,0,0,0.02,1.1),(0,0,0,0.01,0.85,0.85)	(0,0,0,0.02,1,1),(0,0,0,0.01,0.85,0.85)	(0,0,0.01.0.03,1,1),(0,0,0,0.02,0.85,0.85)	(0,0,0.01,0.04,1,1),(0,0,0.01,0.02,0.85,0.85)
C24	(0.01,0.03,0.07,0.14,1.1),(0.01,0.03,0.05,0.13,0.85,0.85)	(0.01,0.03,0.07,0.14,1,1),(0.01,0.03,0.05,0.13,0.85,0.85)	(0.01,0.03,0.07.0.14,1,1),(0.01,0.03,0.05,0.12,0.85,0.85)	(0.01,0.03,0.07,0.14,1,1),(0.01,0.03,0.05,0.13,0.85,0.85)
C25	(0,0,0.01,0.04,1.1),(0,0,0.01,0.03,0.85,0.85)	(0.01,0.02,0.05,0.12,1,1),(0.01,0.02,0.03,0.1,0.85,0.85)	(0,0.01,0.02.0.08,1,1),(0,0.01,0.02,0.06,0.85,0.85)	(0,0,0.01,0.04,1,1),(0,0,0.01,0.03,0.85,0.85)
C31	(0,0,0.01,0.03,1.1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0,0.01,0.03,1,1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0.01,0.02.0.05,1,1),(0,0.01,0.02,0.04,0.85,0.85)	(0,0,0.01,0.03,1,1),(0,0.01,0.01,0.03,0.85,0.85)
C32	(0,0,0.01,0.04,1.1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0.01,0.02,0.04,1,1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0.01,0.02.0.05,1,1),(0,0.01,0.02,0.04,0.85,0.85)	(0,0,0.01,0.04,1,1),(0,0.01,0.01,0.03,0.85,0.85)
C33	(0,0.01,0.02,0.05,1.1),(0,0.01,0.01,0.04,0.85,0.85)	(0,0.01,0.01,0.04,1,1),(0,0.01,0.01,0.04,0.85,0.85)	(0,0.01,0.02.0.05,1,1),(0,0.01,0.02,0.04,0.85,0.85)	(0,0.01,0.02,0.05,1,1),(0.01,0.01,0.02,0.05,0.85,0.85)
C34	(0.01,0.01,0.03,0.07,1.1),(0.01,0.01,0.02,0.06,0.85,0.85)	(0,0.01,0.03,0.06,1,1),(0.01,0.01,0.02,0.06,0.85,0.85)	(0,0.01,0.03.0.06,1,1),(0,0.01,0.02,0.05,0.85,0.85)	(0.01,0.01,0.03,0.07,1,1),(0.01,0.01,0.02,0.06,0.85,0.85)
C35	(0.01,0.03,0.07,0.13,1.1),(0.01,0.04,0.05,0.11,0.85,0.85)	(0.01,0.02,0.04,0.1,1,1),(0.01,0.02,0.03,0.08,0.85,0.85)	(0.01,0.03,0.07.0.13,1,1),(0.01,0.03,0.05,0.11,0.85,0.85)	(0.01,0.03,0.07,0.13,1,1),(0.01,0.04,0.05,0.11,0.85,0.85)
C36	(0,0,0,0.01,1.1),(0,0,0,0.01,0.85,0.85)	(0,0,0.01,0.03,1,1),(0,0,0.01,0.02,0.85,0.85)	(0,0.01,0.01.0.04,1,1),(0,0.01,0.01,0.04,0.85,0.85)	(0,0.01,0.02,0.05,1,1),(0,0.01,0.01,0.04,0.85,0.85)
C37	(0.01,0.03,0.08,0.14,1.1),(0.01,0.04,0.06,0.13,0.85,0.85)	(0,0,0.01,0.05,1,1),(0,0.01,0.01,0.03,0.85,0.85)	(0.01,0.03,0.08.0.14,1,1),(0.01,0.04,0.06,0.13,0.85,0.85)	(0,0.01,0.02,0.07,1,1),(0,0.01,0.02,0.06,0.85,0.85)
C38	(0.01,0.03,0.07,0.13,1.1),(0.01,0.04,0.05,0.11,0.85,0.85)	(0,0.01,0.03,0.07,1,1),(0,0.01,0.02,0.06,0.85,0.85)	(0.01,0.02,0.06.0.12,1,1),(0.01,0.03,0.05,0.1,0.85,0.85)	(0.01,0.03,0.07,0.13,1,1),(0.01,0.04,0.06,0.12,0.85,0.85)
C39	(0.01,0.02,0.05,0.09,1.1),(0.01,0.03,0.04,0.08,0.85,0.85)	(0.01,0.02,0.05,0.09,1,1),(0.01,0.03,0.04,0.08,0.85,0.85)	(0.01,0.02,0.04.0.08,1,1),(0.01,0.02,0.03,0.07,0.85,0.85)	(0.01,0.01,0.03,0.07,1,1),(0.01,0.02,0.02,0.06,0.85,0.85)
C41	(0.01,0.02,0.05,0.09,1.1),(0.01,0.02,0.03,0.09,0.85,0.85)	(0.01,0.01,0.04,0.09,1,1),(0.01,0.02,0.03,0.08,0.85,0.85)	(0.01,0.02,0.04.0.09,1,1),(0.01,0.02,0.03,0.09,0.85,0.85)	(0.01,0.02,0.05,0.09,1,1),(0.01,0.02,0.03,0.09,0.85,0.85)
C42	(0.01,0.02,0.05,0.1,1.1),(0.01,0.02,0.04,0.09,0.85,0.85)	(0.01,0.02,0.05,0.1,1,1),(0.01,0.02,0.04,0.09,0.85,0.85)	(0.01,0.02,0.05.0.1,1,1),(0.01,0.02,0.03,0.09,0.85,0.85)	(0.01,0.02,0.05,0.1,1,1),(0.01,0.02,0.04,0.1,0.85,0.85)
C43	(0.03,0.07,0.23,0.42,1.1),(0.03,0.09,0.17,0.41,0.85,0.85)	(0.01,0.03,0.08,0.24,1,1),(0.01,0.03,0.06,0.19,0.85,0.85)	(0.03,0.07,0.22.0.42,1,1),(0.03,0.09,0.17,0.4,0.85,0.85)	(0.01,0.04,0.13,0.32,1,1),(0.02,0.05,0.1,0.3,0.85,0.85)
C44	(0,0,0.01,0.04,1.1),(0,0.01,0.01,0.03,0.85,0.85)	(0.01,0.01,0.04,0.08,1,1),(0.01,0.02,0.03,0.07,0.85,0.85)	(0.01,0.01,0.04.0.08,1,1),(0.01,0.02,0.03,0.07,0.85,0.85)	(0,0.01,0.01,0.05,1,1),(0,0.01,0.01,0.03,0.85,0.85)
C45	(0,0.01,0.02,0.06,1.1),(0,0.01,0.02,0.05,0.85,0.85)	(0.01,0.01,0.03,0.07,1,1),(0.01,0.02,0.03,0.06,0.85,0.85)	(0,0.01,0.02.0.05,1,1),(0,0.01,0.01,0.04,0.85,0.85)	(0.01,0.01,0.03,0.07,1,1),(0.01,0.02,0.03,0.06,0.85,0.85)
C51	(0,0.01,0.02,0.05,1.1),(0,0.01,0.01,0.05,0.85,0.85)	(0,0.01,0.03,0.07,1,1),(0,0.01,0.02,0.06,0.85,0.85)	(0,0,0.01.0.04,1,1),(0,0.01,0.01,0.04,0.85,0.85)	(0,0.01,0.02,0.06,1,1),(0,0.01,0.02,0.05,0.85,0.85)
C52	(0.01,0.02,0.07,0.16,1.1),(0.01,0.03,0.05,0.15,0.85,0.85)	(0.01,0.02,0.07,0.16,1,1),(0.01,0.03,0.05,0.15,0.85,0.85)	(0.01,0.03,0.09.0.21,1,1),(0.02,0.05,0.07,0.18,0.85,0.85)	(0.01,0.03,0.08,0.2,1,1),(0.01,0.04,0.06,0.16,0.85,0.85)
C53	(0.01,0.03,0.08,0.15,1.1),(0.01,0.04,0.06,0.14,0.85,0.85)	(0.01,0.03,0.07,0.15,1,1),(0.01,0.03,0.06,0.14,0.85,0.85)	(0.01,0.03,0.08.0.15,1,1),(0.01,0.04,0.06,0.14,0.85,0.85)	(0.01,0.03,0.08,0.15,1,1),(0.01,0.04,0.06,0.14,0.85,0.85)
C54	(0,0,0.01,0.04,1.1),(0,0,0.01,0.03,0.85,0.85)	(0,0,0.01,0.04,1,1),(0,0.01,0.03,0.85,0.85)	(0,0,0.01.0.04,1,1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0,0.01,0.04,1,1),(0,0.01,0.01,0.03,0.85,0.85)
C55	(0.02,0.04,0.12,0.23,1.1),(0.02,0.06,0.09,0.21,0.85,0.85)	(0.01,0.04,0.11,0.22,1,1),(0.02,0.05,0.08,0.19,0.85,0.85)	(0.01,0.03,0.1.0.2,1,1),(0.02,0.05,0.07,0.18,0.85,0.85)	(0.02,0.04,0.12,0.23,1,1),(0.02,0.06,0.09,0.21,0.85,0.85)

TABLE 8. The Weighted Decision Matrix (this table is continued on the next page)

	Geothermal Energy	Natural Gas	Oil	Coal
C11	(0,0,0.01,0.02,1,1),(0,0,0.01,0.02,0.85,0.85)	(0,0,0.01,0.03,1,1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0,0.01,0.03,1,1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0.01,0.02,0.04,1,1),(0,0.01,0.01,0.03,0.85,0.85)
C12	(0,0,0,0,1,1),(0,0,0,0,0.85,0.85)	(0,0,0,0.01,1,1),(0,0,0,0.01,0.85,0.85)	(0,0,0.01,0.02,1,1),(0,0,0.01,0.02,0.85,0.85)	(0,0,0.01,0.02,1,1),(0,0,0.01,0.02,0.85,0.85)
C13	(0,0.01,0.01,0.03,1,1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0,0,0.01,1,1),(0,0,0,0.01,0.85,0.85)	(0,0,0,0.01,1,1),(0,0,0,0.01,0.85,0.85)	(0,0,0,0.01,1,1),(0,0,0,0.01,0.85,0.85)
C14	(0,0,0.01,0.02,1,1),(0,0,0,0.01,0.85,0.85)	(0,0,0.01,0.02,1,1),(0,0,0.01,0.02,0.85,0.85)	(0,0,0.01,0.03,1,1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0,0.01,0.03,1,1),(0,0.01,0.01,0.03,0.85,0.85)
C15	(0,0,0.01,0.02,1,1),(0,0,0,0.01,0.85,0.85)	(0,0,0.01,0.02,1,1),(0,0,0,0.02,0.85,0.85)	(0,0,0.01,0.02,1,1),(0,0,0.01,0.02,0.85,0.85)	(0,0,0.01,0.02,1,1),(0,0,0,0.01,0.85,0.85)
C16	(0,0,0.01,0.03,1,1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0,0.01,0.02,1,1),(0,0,0,0.02,0.85,0.85)	(0,0,0,0.01,1,1),(0,0,0,0.85,0.85)	(0,0,0,0.01,1,1),(0,0,0,0.01,0.85,0.85)
C17	(0,0,0.01,0.02,1,1),(0,0,0,0.01,0.85,0.85)	(0,0,0,0.01,1,1),(0,0,0,0.01,0.85,0.85)	(0,0,0,0.01,1,1),(0,0,0,0.01,0.85,0.85)	(0,0,0,0.01,1,1),(0,0,0,0.85,0.85)
C21	(0,0.01,0.02,0.06,1,1),(0,0.01,0.01,0.04,0.85,0.85)	(0,0.01,0.02,0.06,1,1),(0,0.01,0.01,0.05,0.85,0.85)	(0.01,0.01,0.03,0.08,1,1),(0.01,0.02,0.03,0.07,0.85,0.85)	(0.01,0.01,0.04,0.08,1,1),(0.01,0.02,0.03,0.07,0.85,0.85)
C22	(0,0.01,0.01,0.03,1,1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0,0.01,0.03,1,1),(0,0.01,0.01,0.02,0.85,0.85)	(0,0,0,0.01,1,1),(0,0,0,0.85,0.85)	(0,0,0,0.01,1,1),(0,0,0,0.85,0.85)
C23	(0,0,0.01,0.03,1,1),(0,0,0.01,0.02,0.85,0.85)	(0.01,0.01,0.03,0.08,1,1),(0.01,0.02,0.02,0.06,0.85,0.85)	(0.01,0.02,0.04,0.09,1,1),(0.01,0.02,0.03,0.08,0.85,0.85)	(0.01,0.02,0.05,0.1,1,1),(0.01,0.03,0.04,0.08,0.85,0.85)
C24	(0.01,0.03,0.07,0.14,1,1),(0.01,0.03,0.05,0.12,0.85,0.85)	(0,0.01,0.03,0.08,1,1),(0,0.01,0.02,0.06,0.85,0.85)	(0,0.01,0.02,0.07,1,1),(0,0.01,0.02,0.05,0.85,0.85)	(0,0.01,0.02,0.06,1,1),(0,0.01,0.01,0.04,0.85,0.85)
C25	(0,0.02,0.04,0.11,1,1),(0.01,0.02,0.03,0.08,0.85,0.85)	(0.01,0.03,0.09,0.18,1,1),(0.02,0.04,0.07,0.16,0.85,0.85)	(0.02,0.04,0.09,0.19,1,1),(0.02,0.05,0.07,0.17,0.85,0.85)	(0.02,0.04,0.09,0.18,1,1),(0.02,0.05,0.07,0.16,0.85,0.85)
C31	(0,0,0.01,0.03,1,1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0,0.01,0.03,1,1),(0,0.01,0.02,0.85,0.85)	(0,0.01,0.01,0.04,1,1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0.01,0.01,0.04,1,1),(0,0.01,0.01,0.03,0.85,0.85)
C32	(0,0,0.01,0.03,1,1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0,0.01,0.04,1,1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0.01,0.02,0.04,1,1),(0,0.01,0.01,0.04,0.85,0.85)	(0,0.01,0.02,0.04,1,1),(0,0.01,0.01,0.04,0.85,0.85)
C33	(0,0.01,0.01,0.04,1,1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0,0.01,0.03,1,1),(0,0,0.01,0.03,0.85,0.85)	(0,0,0.01,0.02,1,1),(0,0,0,0.02,0.85,0.85)	(0,0.01,0.02,0.04,1,1),(0,0.01,0.01,0.04,0.85,0.85)
C34	(0,0.01,0.03,0.06,1,1),(0,0.01,0.02,0.05,0.85,0.85)	(0,0,0,0.01,1,1),(0,0,0,0.01,0.85,0.85)	(0,0,0,0.02,1,1),(0,0,0,0.01,0.85,0.85)	(0,0,0,0.02,1,1),(0,0,0,0.01,0.85,0.85)
C35	(0.01,0.02,0.05,0.1,1,1),(0.01,0.02,0.04,0.08,0.85,0.85)	(0,0.02,0.04,0.09,1,1),(0.01,0.02,0.03,0.1,0.85,0.85)	(0,0.01,0.02,0.07,1,1),(0,0.01,0.02,0.05,0.85,0.85)	(0.01,0.02,0.06,0.12,1,1),(0.01,0.03,0.05,0.11,0.85,0.85)
C36	(0,0,0.01,0.03,1,1),(0,0,0.01,0.02,0.85,0.85)	(0,0.01,0.03,0.06,1,1),(0,0.01,0.02,0.05,0.85,0.85)	(0.01,0.02,0.04,0.08,1,1),(0.01,0.02,0.03,0.07,0.85,0.85)	(0.01,0.01,0.04,0.07,1,1),(0.01,0.02,0.03,0.06,0.85,0.85)
C37	(0,0.01,0.03,0.08,1,1),(0,0.01,0.02,0.08,0.85,0.85)	(0,0,0.01,0.04,1,1),(0,0.01,0.03,0.85,0.85)	(0,0,0,0.02,1,1),(0,0,0,0.01,0.85,0.85)	(0,0,0,0.02,1,1),(0,0,0,0.01,0.85,0.85)
C38	(0.01,0.02,0.06,0.12,1,1),(0.01,0.03,0.05,0.11,0.85,0.85)	(0,0,0,0.02,1,1),(0,0,0,0.01,0.85,0.85)	(0,0,0.01,0.04,1,1),(0,0,0.01,0.02,0.85,0.85)	(0,0,0.01,0.04,1,1),(0,0.01,0.01,0.03,0.85,0.85)
C39	(0,0,0.01,0.04,1,1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0,0.01,0.03,1,1),(0,0,0.01,0.02,0.85,0.85)	(0,0,0.01,0.03,1,1),(0,0,0.01,0.02,0.85,0.85)	(0,0.01,0.02,0.04,1,1),(0,0.01,0.01,0.04,0.85,0.85)
C41	(0.01,0.01,0.04,0.09,1,1),(0.01,0.02,0.03,0.08,0.85,0.85)	(0,0,0.01,0.03,1,1),(0,0,0,0.02,0.85,0.85)	(0,0,0,0.02,1,1),(0,0,0,0.01,0.85,0.85)	(0,0,0,0.03,1,1),(0,0,0,0.02,0.85,0.85)
C42	(0.01,0.02,0.04,0.1,1,1),(0.01,0.02,0.03,0.09,0.85,0.85)	(0.01,0.01,0.04,0.09,1,1),(0.01,0.02,0.03,0.08,0.85,0.85)	(0,0,0.01,0.04,1,1),(0,0.01,0.01,0.03,0.85,0.85)	(0,0.01,0.02,0.05,1,1),(0,0.01,0.01,0.04,0.85,0.85)
C43	(0.02,0.06,0.21,0.42,1,1),(0.03,0.08,0.16,0.39,0.85,0.85)	(0,0.02,0.07,0.21,1,1),(0.01,0.03,0.05,0.16,0.85,0.85)	(0,0,0.02,0.1,1,1),(0,0.01,0.01,0.06,0.85,0.85)	(0,0.01,0.02,0.13,1,1),(0,0.01,0.02,0.08,0.85,0.85)
C44	(0,0.01,0.02,0.06,1,1),(0,0.01,0.02,0.05,0.85,0.85)	(0.01,0.01,0.04,0.08,1,1),(0.01,0.02,0.03,0.07,0.85,0.85)	(0.01,0.01,0.04,0.09,1,1),(0.01,0.02,0.03,0.08,0.85,0.85)	(0.01,0.02,0.05,0.09,1,1),(0.01,0.02,0.04,0.09,0.85,0.85)
C45	(0,0.01,0.02,0.05,1,1),(0,0.01,0.02,0.04,0.85,0.85)	(0,0.01,0.02,0.06,1,1),(0,0.01,0.02,0.05,0.85,0.85)	(0,0.01,0.02,0.05,1,1),(0,0.01,0.01,0.04,0.85,0.85)	(0.01,0.01,0.04,0.07,1,1),(0.01,0.02,0.03,0.07,0.85,0.85)
C51	(0,0.01,0.03,0.07,1,1),(0,0.01,0.02,0.07,0.85,0.85)	(0,0.01,0.02,0.06,1,1),(0,0.01,0.02,0.06,0.85,0.85)	(0.01,0.01,0.03,0.08,1,1),(0.01,0.02,0.03,0.08,0.85,0.85)	(0.01,0.01,0.03,0.08,1,1),(0.01,0.02,0.03,0.08,0.85,0.85)
C52	(0.01,0.03,0.08,0.18,1,1),(0.01,0.04,0.06,0.16,0.85,0.85)	(0.02,0.04,0.11,0.23,1,1),(0.02,0.06,0.09,0.2,0.85,0.85)	(0.02,0.04,0.11,0.23,1,1),(0.02,0.06,0.09,0.2,0.85,0.85)	(0.02,0.04,0.11,0.23,1,1),(0.02,0.06,0.09,0.2,0.85,0.85)
C53	(0.01,0.03,0.07,0.15,1,1),(0.01,0.03,0.06,0.14,0.85,0.85)	(0.01,0.02,0.06,0.14,1,1),(0.01,0.03,0.05,0.12,0.85,0.85)	(0.01,0.02,0.05,0.13,1,1),(0.01,0.02,0.04,0.1,0.85,0.85)	(0.01,0.02,0.06,0.14,1,1),(0.01,0.03,0.05,0.12,0.85,0.85)
C54	(0,0.01,0.02,0.05,1,1),(0,0.01,0.01,0.04,0.85,0.85)	(0,0.01,0.03,0.07,1,1),(0,0.01,0.02,0.06,0.85,0.85)	(0,0.01,0.03,0.07,1,1),(0.01,0.01,0.02,0.06,0.85,0.85)	(0,0.01,0.03,0.07,1,1),(0.01,0.01,0.02,0.06,0.85,0.85)
C55	(0.01,0.03,0.08,0.19,1,1),(0.01,0.04,0.06,0.16,0.85,0.85)	(0,0.02,0.05,0.13,1,1),(0.01,0.02,0.04,0.1,0.85,0.85)	(0,0.01,0.02,0.08,1,1),(0,0.01,0.02,0.06,0.85,0.85)	(0,0.01,0.02,0.08,1,1),(0,0.01,0.02,0.06,0.85,0.85)

Energy Alternative	*Cci*	*Ranking*
Wind	0.927	1
Solar	0.919	2
Geothermal	0.903	3
Biofuel	0.889	4
Hydro Energy	0.853	5
Natural Gas	0.816	6
Coal	0.791	7
Oil	0.783	8

TABLE 9. The Ranking of Energy Alternatives

4. **Discussion**

In this paper, an integrated fuzzy MCDM methodology based on type-2 fuzzy sets for selection among energy alternatives in Turkey is suggested. According to the results obtained, the first energy alternative that is the most suitable and preferable alternative for Turkey is determined as wind energy as shown in Table 8. The alternative wind energy is renewable and does not harm the environment, and is a natural source of energy. Moreover the production of electricity with wind energy does not cause to the CO_2 emissions and this type of energy does not lead to acid rain and atmospheric warming. An energy source can be considered as a continuous and endless [27]. The second alternative is determined as solar energy is also renewable, clean and environment friendly source of energy. Solar energy is converted to electrical energy with the help of photovoltaic cells or can be converted to heat energy with the aid of heating systems. A significant portion of the year in many parts of Turkey to be sunny makes area of usage for solar energy larger. The third, fourth and fifth alternatives are also determined as the geothermal, biomass and hydro energies, respectively. These are also renewable, infinite and clean energy sources. To prefer to use of these resources for primarily will be suitable from the point of government policies, environmental and social issues. The worst alternatives are determined as the natural gas, oil and coal resources such as fossil fuels. During their use, especially oil and coal, pose a threat to human health by carbon emissions to the environment. Therefore, it will be better not to use them primarily.

4.1. **Sensitivity Analysis.** An analysis called sensitivity is a critical section in decision making. It analyzes the effects of decision parameters on the results. In this subsection, a sensitivity analysis is conducted by changing the weights of the main criteria. For this aim, different scenarios are obtained by changing weights of the main criteria. Thus, it is examined their impacts on the results. For this aim, the following scenarios are analyzed:
Scenario 1: Change the weight of technological and environmental criteria,
Scenario 2: Change the weight of technological and economical criteria,
Scenario 3: Change the weight of technological and socio-political criteria,
Scenario 4: Change the weight of technological and technical criteria,

Scenario 5: Change the weight of environmental and economical criteria,
Scenario 7: Change the weight of environmental and socio-political criteria,
Scenario 8: Change the weight of environmental and technical criteria,
Scenario 9: Change the weight of the economic and socio-political criteria,
Scenario 9: Change the weight of the socio-political and technical criteria.
These scenarios are also analyzed by using the proposed MCDM method based on type-2 fuzzy sets. The obtained ranking results of each scenario are shown in Figure 5.

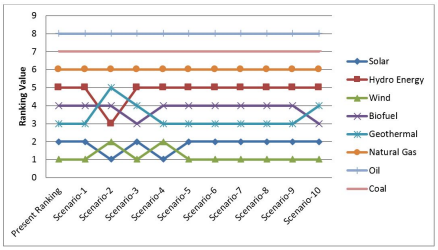


FIGURE 5. The Results of the Sensitivity Analysis

According to Figure 5, the wind and solar energy alternatives are determined as the first and second energy alternative for all of the scenarios. The energy alternatives of oil, coal and natural gas are also determined that should not be preferred in all of these scenarios.

5. **Conclusion and Policy Implications**

Energy decision making problems are complex multi-criteria problems that have numerically qualified and nonqualified criteria. One of the most commonly used methods to solve these problems is decision analysis that is intended to selection of the best or the most preferred alternative. In many decision-making problems, exact numerical values may not be able to use during evaluation stages. In such a case, the decision makers define their preferences with linguistic variables. FST is used to eliminate the uncertainty arising from this situation. When we aim to reduce the level of uncertainty and obtain more realistic results, the type-2 fuzzy sets can be applied to reflect better uncertainty. Therefore, using multi- criteria decision-making methods with type-2 fuzzy sets in the problems that have high uncertainty and are complex satisfy closer result to reality and the effect of the uncertainty will be minimized.
In this paper, ranking of energy alternatives for Turkey is clarified by using an integrated fuzzy MCDM methodology that consists of type-2 fuzzy AHP and type-2 fuzzy TOPSIS. To consider the uncertainty in decision making process, FST is applied and linguistic expressions are used in the evaluation process. In order to increase the degree of fuzziness, both calculating the weights of criteria and ranking of alternatives, interval type-2 fuzzy sets are used. Firstly, the criteria that affect the alternatives are weighted by using type-2 fuzzy AHP. The next evaluations are carried out according to these weights by using type-2 fuzzy TOPSIS. According to the

obtained results, renewable energy alternatives have been determined as the most suitable energy alternatives for future investments of energy in Turkey. The first energy alternative is clarified as wind energy that does not cause climate change, has lower fuel costs in terms of energy security and reduce the risks of dependence on other countries in terms of political and supply. To use this resource in Turkey primarily will be useful from the point of technical, technological, economic, socio-political and environmental aspects. In future studies, the others MCDM methods can be applied to evaluate energy alternatives.

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