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RESEARCH PAPER

Identifying and Prioritizing the Factors Affecting Renewable Energy Development: A Case Study

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ABSTRACT
Compared to coal and other fossil fuels, renewable energy (RE) sources emit significantly less carbon dioxide (CO_2). In this sense, switching to such sources brings many positive effects to the environment through mitigating climate change, so the terms green energy and clean energy, have been derived from these constructive environmental impacts. Given the utmost importance of RE development, the primary objective of this study was to identify and prioritize the effective RE development strategies in Mazandaran Province, Iran, using different methods, including the Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis, along with other decision-making techniques. Recruiting a team of 11 industrial and academic experts, the strategies to implement in this region were developed in line with the RE development plans. For this purpose, the Multi-Criteria Decision-Making (MCDM) methodologies were utilized within the gray fuzzy environment to manage the existing uncertainties. The Gray-Additive Ratio Assessment System (Gray ARAS) was further applied to rank the main factors at each level. According to the SWOT analysis and the Stepwise Weight Assessment Ratio Analysis (SWARA) outcomes, among the major factors shaping RE development in Mazandaran Province, Iran, the economic criterion, with the final weight of 0.24, was ranked first; and then the geographical and environmental criteria, having the final weights of 0.23 and 0.19, were put in the second and third places, respectively. In this regard, appropriate location, with the final weight of 0.226, was ranked first; and subsequently pollution reduction and energy production costs, receiving the final weights of 0.103 and 0.094, were the second and third sub-criteria, respectively. As a final point, the validation results based on the Gray-Weighted Aggregated Sum Product Assessment (Gray-WASPAS) and ranking obtained through the Gray-ARAS were confirmed.

KEYWORDS: *Renewable energy; Ranking; Mazandaran province; SWOT; SWARA; Gray-ARAS; Gray-WASPAS.*

1. Introduction

Following population growth in recent years, energy has become a critical source in the development of economic activities as well as individual and social welfare. An accurate understanding of energy demand in various sectors is thus vital for energy planning and policymaking worldwide. Energy demand is typically influenced by a wide variety of socioeconomic factors, such as population, urbanization, industrialization, capital net income, and technological progress, among others. Energy production system in general and electricity production in particular are accordingly among the significant contributors to greenhouse gas (GHG) emissions. In this line, environmental concerns and ending fossil fuels

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have necessitated a shift in energy production system and the replacement of fossil fuels. From this perspective, renewable energy (RE) sources, such as hydroelectric power, have been acknowledged as a viable alternative to fossil fuels [1]. In Iran, fossil fuels account for nearly 90% of electricity generation [2]. Such fuels cause environmental troubles, such as ozone depletion, global warming, and acid rains [3, 4]. The upshots of climate change have also become progressively more obvious in numerous components of this sector, wherein flash floods, freak droughts, and intense storms have occurred [5].

According to scientific estimates, carbon dioxide (CO_2) emissions induced by fossil fuel consumption, as the primary cause of global warming, have significantly redoubled to the point where they will account for 60% of GHG emissions by the end of 2030 [6]. With regard to more public attention devoted to ecosystem degradation and technological advances, RE sources are becoming increasingly important as they replace the traditional ones [7]. Such sources are respected as clean energy ones because they are derived from natural sources, such as wind, sunlight, rain, geothermal heat, and tidal waves [8, 9]. These types of energy, which are typically based on environmental scientific innovations, can thus have effects on the existing pollution trends [10].

Iran, a developing country with a population of 80 million, is the second-biggest producer of oil in the Organization of the Petroleum Exporting Countries (OPEC), and even the second-largest natural gas producer globally [11]. Currently, RE production is critical due to the scarcity of fossil fuel sources. Iran's high annual growth in energy consumption as well as its exit from the group of oil exporters at the end of the current century will accordingly have an impact on development plans in this country [12]. In other words, for Iran, as a country rich in natural resources, economic dependence on crude oil and gas is another critical factor that calls for RE development, because this has resulted in its underdevelopment and sluggish economic growth in recent years [13].

Among the RE development capabilities in Iran, geographical diversity has enhanced this country with significant clean sources, such as solar and geothermal energy, wind, and hydropower [11]. The most common renewable alternatives to fossil fuels are sustainable energy sources, such as solar energy [14, 15], and Iran's location in the global solar belt has provided a good opportunity to exploit this green energy. This country has an area of about 1.6 million km^2, 300 sunny d/y, and an average solar radiation of 2200 kWh/m^2/y. Every year, Iran also receives over 2800 h of sunlight. As a result, even if the energy from solar sources is absorbed from only 1% of Iran's land area with 10% system efficiency, 9 million MWh of energy comes from the daily sunshine [16]. Based on the information in Figure 1 for the RE capacities in Iran's electricity, solar energy has the largest share of all renewable sources in terms of electricity generation in Iran by 44% in April 2020, and 63 different power plants.

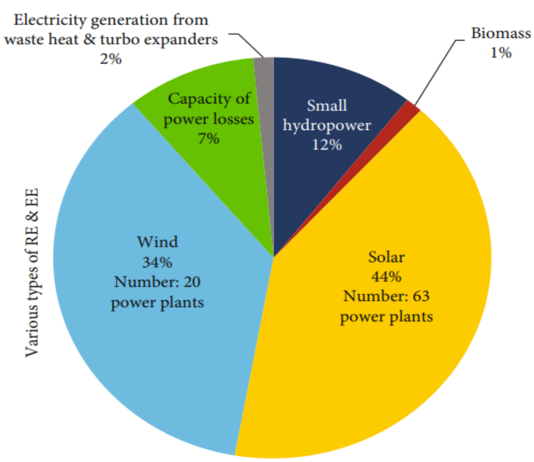

Fig. 1. Proportion of different types of RE in Iran's electricity generation [17]

In light of this, the capabilities of wind energy in Iran were investigated in the present study. Of note, the creation of Iran's wind atlas has been among the most significant projects for wind energy improvement. This project is being implemented by Renewable Energy and Energy Efficiency Organization of Iran (SATBA), and is also one of the national wind energy projects. Based on the data from the Global Wind Atlas and 60 stations nationwide, the main sites have an estimated output of approximately 60,000 MW. Iran's wind energy potential is also projected to be over 18,000 MW, demonstrating the country's significant potential for wind power generation and the cost-effectiveness of investment in the wind energy industry. As a result, Iran's wind power potential is estimated to be 100,000 MW [18]. Figure 2 classifies Iran's provinces according to their geographical policy scores for wind energy development.

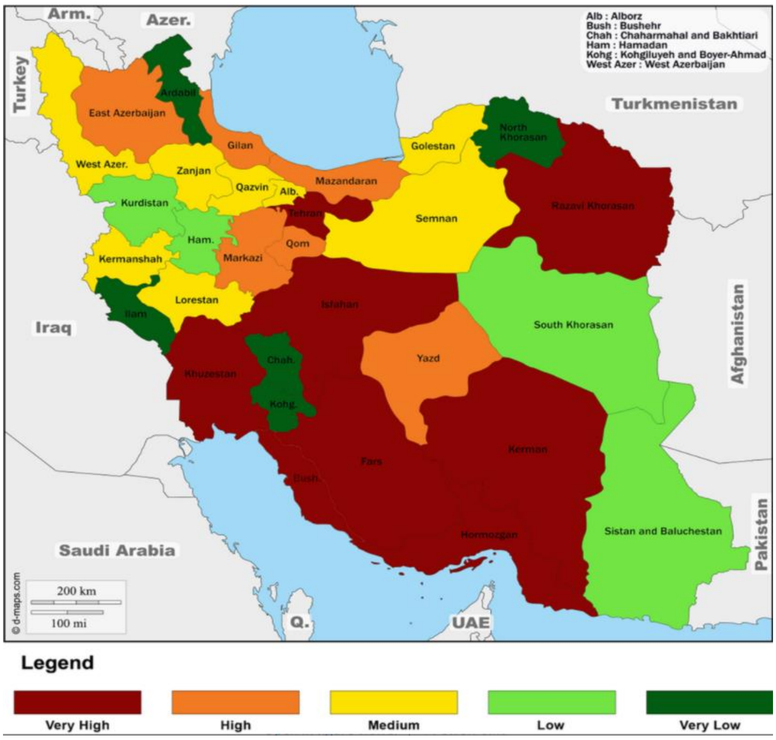

Fig. 2. Final position of Iran's provinces in terms of geographical policies for the development [19]

Mazandaran Province, Iran, is characterized by ideal capabilities and potentials for the installation and operation of wind turbines, based on the results in Figure 2, and with respect to its geographical location and diverse climatic features (SATBA). Given the increased use of wind energy for electricity generation, it seems necessary to locate suitable areas for the establishment of wind farms in the northern regions while protecting the environment [20]. It is also possible to make the best use of energy sources from waves, with regard to the unique climatic conditions in this region, the presence of the Caspian Sea, and appropriate winds. Although radiation in this province is lower than that in many southern and central provinces of Iran throughout the year, there are good capacities for exploiting solar energy, as one of the RE sources in this region (SATBA).

Iran has much potential in the field of RE. Despite the fact that no RE development strategies have been established in Iran, the majority of the energy supply in this country is provided by burning fossil fuels and only a small portion of the RE potential is utilized. As a result, the optimal combination of RE development strategies in Iran was determined in this study by employing different methods, such as the Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis, the Multi-Criteria

Decision-Making (MCDM) techniques, as well as Game Theory (GT).

Reviewing the existing literature revealed that the majority of studies determining RE strategies had only recruited the SWOT analysis. Moreover, the proposed factors and strategies have not yet been prioritized in the SWOT matrix, but the environmental factors have been examined qualitatively. To deal with the weaknesses of the SWOT analysis, the MCDM methods with a spectrum of gray fuzzy numbers were used in this study to account for the uncertainty of linguistic variables in the real world.

This study was organized as follows. The t related literature in this field was examined in Section 2. The materials and methods, such as the SWOT analysis, the Stepwise Weight Assessment Ratio Analysis (SWARA), and the Gray-Additive Ratio Assessment System (Gray-ARAS) technique were introduced in Section 3. As well, Section 4 presented the data analysis, and Section 5 included the findings and recommendations.

The present study was to develop the main strategies for RE development in Mazandaran Province, Iran. As no investigation had been already conducted to formulate strategies for RE sources in this province, to the best of authors' knowledge, this study could help expand the existing literature regarding RE development in Iran. Reviewing previous studies indicated that the majority had reflected on determining RE strategies only based on the SWOT analysis, wherein the recommended strategies and associated factors had not been prioritized, but there was just a qualitative analysis of the environmental factors. To tackle the weaknesses of the SWOT analysis, the MCDM methodologies with the range of gray fuzzy numbers were utilized for considering the uncertainties in the linguistic variables within the real world.

2. Literature Review

Ever-growing global population, rising energy demands, and enhanced environmental awareness have all led people from all walks of life to develop and use RE sources. Furthermore, such clean sources are not to run out, do not emit GHGs, and are available everywhere and to everyone, irrespective of the political and geographical boundaries. RE sources also give birth to new industries, boost national economy, create new jobs, provide economical energy, and at the same time, minimize the adverse effects of conventional energy sources [21].

It is widely accepted that the disparity between fossil fuels and RE sources in the energy system not only poses challenges to many countries in managing the interplay between energy, economy, and the environment, but more significantly, it also exacerbates the climate crisis due to the substantial amount of CO_2 emissions [22, 23] from coal consumption, which have surpassed 10 billion TPY. It is a general trend to strongly promote the development of green and low-carbon RE sources in order to reduce CO_2 emissions caused by fossil fuels while meeting the energy needs of economic development. Given the high consumption rate of fossil fuels and large CO_2 emissions in developing countries, RE development seems to be an effective way to cut CO_2 emissions [24]. To put it another way, humanity is currently confronted with the challenge of climate change, which necessitates the formulation of RE development strategies [25]. In this regard, researchers have thus far studied the application of RE to meet energy demands in various sectors due to the increasing need for energy and the gradual reduction of global fossil fuel sources [26]. Considering the significance of this issue, previous studies have mostly investigated RE development strategies, employing the SWOT matrix and the MCDM techniques to accomplish this goal. Figure 3 shows that the bulk of research has been conducted in the fields of RE, energy planning, and sustainable energy from 2003 to 2020.

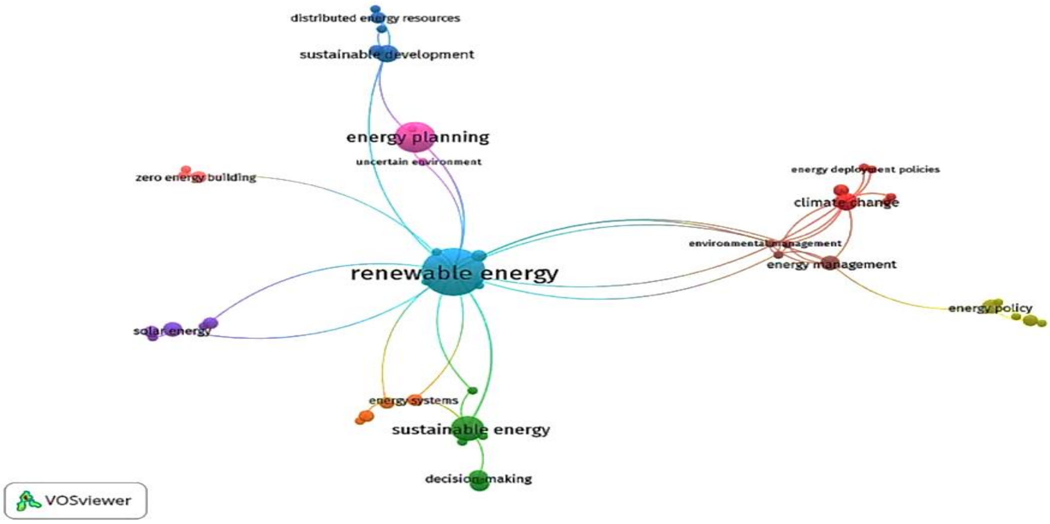

Fig. 3. Context, topic, and various disciplines used in energy-related research from 2003 to 2020 [27]

To expand RE sources, it is necessary to make decisions about the required development strategies. The main steps in the strategic decision-making process are thus (i) strategy formulation, (ii) implementation, and (iii) evaluation. Moreover, the SWOT analysis of threats and opportunities as the external factors, as well as weaknesses and strengths as the internal ones, is critical for strategy formulation and development [28]. Nonetheless, the use of the SWOT analysis has some flaws, as the prioritization of the relevant factors and the proposed strategies are not taken into account. The number of recommended strategies has greatly augmented as the number of factors has multiplied, but this analysis merely examines the impact of environmental factors qualitatively, but with no high accuracy. Researchers have recently utilized the MCDM methods to deal with the weaknesses of the SWOT analysis because formulating a strategy is a decision-making problem involving multiple criteria. The MCDM technique is thus a branch of operations research (OR) that assists decision-makers and policymakers in selecting and prioritizing strategies based on a wide variety of competing criteria [29, 30]. Table 1 summarizes previous research in this field.

Given the importance of RE sources and the necessity of their development, as well as the fact that Mazandaran Province, Iran, has the highest non-RE consumption rate due to the existence of industries, such as agriculture and tourism, there is a need to develop this type of energy. Nonetheless, RE development as a multifaceted process necessitates the consideration of various strategies to implement the existing policies in this field. In other words, RE development in this province is hampered by some limitations, such as no public support for reforming consumption patterns, insufficient foreign investment due to sanctions, vast oil and gas reserves in Iran, subsidies allocated to fossil fuel sources, oil-oriented economic approaches and views, less attention to private-sector cooperation, and high initial investment costs. Developing RE development strategies is thus a very complex process that requires a scientific method to realize. As a result, the primary objective of this study was to assess the effective RE development strategies in Mazandaran Province, Iran. To do so, this study employed an integrated methodological approach, consisting of the SWOT analysis, SWARA, and the Gray-ARAS technique to select the best strategies in terms of strengths, weaknesses, opportunities, and threats. The main objective in this regard was to address the complexities of the RE development process. In this study, a SWOT matrix was thus practiced to analyze various RE development strategies.

Tab. 1. Studies determining RE strategies

Researchers	Study setting	Approach		MCDM method										Energy							Main criterion						Production	
		MCDM	SWOT analysis	VIKOR	ANP	AHP	Fuzzy-AHP	TOPSIS	Fuzzy-TOPSIS	SWARA	Gray-WASPAS	PROMETHEE II	ARAS	Nuclear energy	Wind	Sunlight	Water	Biomass	Geothermal heat	Sea waves	Geography	Technology	Economy	Environment	Social welfare	Assurance & Safety	Electricity (power plant)	Hydrogen
Solangi et al. (2019) [30]	Pakistan		✓			✓			✓						✓	✓	✓	✓	✓		✓	✓	✓	✓			✓	
Mostafaei pour et al. (2020) [31]	Afghanistan	✓		✓				✓		✓			✓		✓				✓		✓	✓			✓		✓	✓
Erdoğan & Kaya (2016) [32]	Turkey	✓				✓		✓						✓							✓	✓	✓		✓	✓		
Haddad et al. (2017) [33]	Algeria	✓				✓									✓	✓	✓	✓	✓			✓	✓	✓	✓		✓	
Hussain Mirjat et al. (2018) [34]	Pakistan	✓				✓									✓	✓	✓	✓				✓	✓	✓	✓		✓	
Norouzi et al. (2020) [35]	Iran	✓		✓			✓								✓	✓		✓				✓	✓	✓	✓		✓	
Abdul et al. (2022) [36]	Pakistan	✓		✓		✓									✓	✓		✓	✓			✓	✓	✓	✓		✓	
Çolak & Kaya (2017) [37]	Turkey	✓					✓		✓						✓	✓		✓	✓	✓		✓	✓	✓	✓		✓	
Shao et al. (2020) [38]	Pakistan	✓				✓		✓							✓	✓	✓	✓	✓			✓	✓	✓	✓		✓	
Kamran et al. (2020) [39]	China	✓				✓														✓		✓	✓	✓			✓	
Wang & Solangi (2020) [40]	Turkey	✓	✓		✓				✓						✓		✓		✓		✓	✓	✓	✓			✓	
Indrajaya nthan et al. (2022) [41]	India	✓	✓				✓					✓			✓	✓						✓	✓	✓			✓	
Karatop et al. (2022) [42]	Turkey	✓	✓				✓								✓	✓	✓	✓	✓				✓				✓	✓
Ervural et al. (2018) [43]	Pakistan	✓	✓				✓								✓	✓		✓				✓	✓	✓	✓		✓	
Present study	Iran (Mazandaran Province)	✓	✓							✓	✓		✓		✓	✓				✓	✓	✓	✓	✓	✓	✓	✓	

2.1. Innovations, literature gap, and study contributions

A review of the related works demonstrated that they had mostly focused on energy, and the main strengths, weaknesses, threats, and opportunities had been examined using the SWOT analysis, but the importance of the existing criteria had not been determined. In the present study, the MCDM methods were used in the gray fuzzy environment to resolve the current uncertainties. Considering that the MCDM techniques could evaluate only the recent situation of the criteria affecting RE development, this study investigated RE development in Mazandaran Province, Iran, for the future time horizon. Therefore, the MCDM techniques were employed to eliminate the shortcomings. Furthermore, this study was conducted in Mazandaran Province, so it was an innovation among the case studies regarding RE development. As a final point, the Gray-Weighted Aggregated Sum Product Assessment (Gray-WASPAS) was integrated to validate the output accuracy.

3. Case Study Specifications: Mazandaran Province, Iran

The climate in Iran is complex, in a spectrum from subtropical to sub-polar. In iciness, an excessive-stress belt, targeted in Siberia, slashes the west and the south to the interior of the Iranian Plateau, whilst low strain structures amplify in the warmer waters of the Caspian Sea, the Persian Gulf, as well as the Mediterranean Sea [44]. Mazandaran Province, positioned within the north of Iran and the southern coastline of the Caspian Sea, is located in the approximate geographical role of 35 and 36 levels east and 50 to 54 levels north. According to the 2015 census, this province has a population of more than 3.2 million, which is about 4.2% of the entire country's population. In Figure 4, Mazandaran Province is bounded by the Caspian Sea from the north, Qazvin, Alborz, Tehran, and Semnan Provinces from the south, and also the Provinces of Gilan and Golestan from the west to the east. Of note, it clearly has a strategic geographical location.

Fig. 4. Geographical location of the case study (mazandaran province and its cities) [45]

4. Methodology

A descriptive survey was used in this applied study for data collection purposes. Moreover, it was categorized as a qualitative-quantitative research in terms of the process and method of data collection and analysis. The SWARA and Gray-ARAS decision-making techniques were further recruited to analyze the data obtained through the SWOT matrix via interviews with 11 faculty members, researchers, and experts in RE sources, along with a literature review.

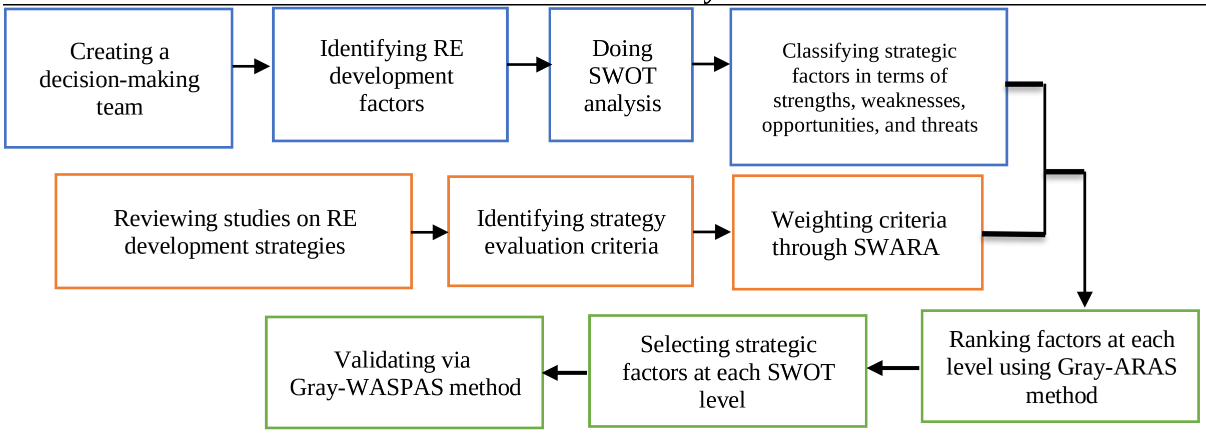

Fig. 5. Research steps

4.1. SWOT analysis

The SWOT analysis represents a method for identifying internal and external strengths and weaknesses, as well as opportunities and threats. It is frequently applied in strategic planning and thus suits mapping the possibilities (viz., strengths and opportunities) and challenges (i.e., weaknesses and threats) of the chosen field [46]. A SWOT matrix can thus include various strategies related to its dimensions and factors, which are typically created using the strength-threat (ST), strength-opportunity (SO), weakness-threat (WT), and weakness-opportunity (WO) strategies. Figure 6 depicts the strategies related to the SWOT dimensions.

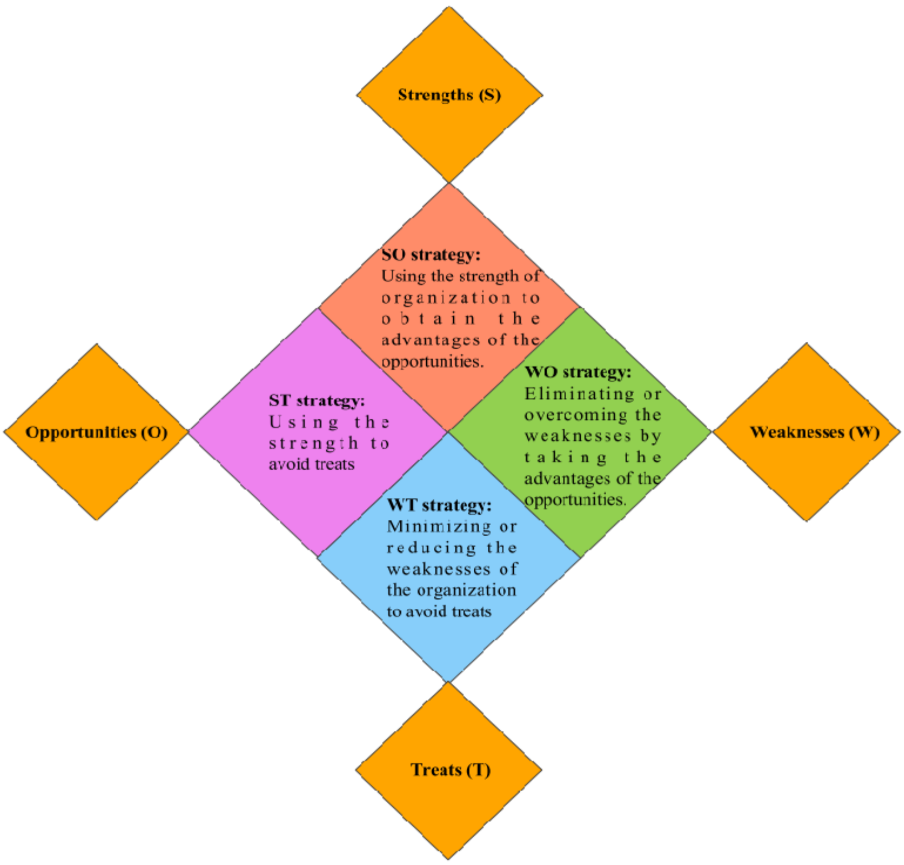

Fig. 6. SWOT strategies [47]

4.2. SWARA method

Keršuliene et al. developed the SWARA approach in 2010, as one of the weight-value determination methods with an important role in decision-making [48]. The ability and possibility of evaluating the accuracy of expert opinions about the importance of criteria in the process of determining their weight have been among the main features or the advantages of the present method.

The following are the basic steps for weighting, using the SWARA method [49]:

- Sort the indices
- Calculate the relative importance of each index (S_j)
- Compute the coefficient K_j

The coefficient K_j is calculated using Eq. 1 as a function based on the relative importance of each index [50], as follows:

$$K_j = S_j + 1 \tag{1}$$

- Determine the initial weight of each index

Eq. 2 is applied to gain the primary weight of the indices. In this context, the weight of the first index, which is the most important one, is set to 1 [51]:

$$q_j = \frac{q_{j-1}}{K_j} \tag{2}$$

- Compute the final normal weight

The latest weight of each index, also known as the normalized weight, is calculated in the final step of the SWARA method, using Eq. 3 [52]:

$$w_j = \frac{q_j}{\sum q_j} \tag{3}$$

4.3. Gray-ARAS method

The steps of the Gray-ARAS method are as follows:

- In the first step, the gray decision matrix is created. Moreover, the dimensions of this matrix are *mxn*, wherein *m* indicates the number of options (rows) and *n* refers to the number of the criteria (columns) [53]:

$$X = \begin{bmatrix} \otimes x_{01} & \cdots & \otimes x_{0j} & \cdots & \otimes x_{0n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \otimes x_{i1} & \cdots & \otimes x_{ij} & \cdots & \otimes x_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \otimes x_{m1} & \cdots & \otimes x_{mj} & \cdots & \otimes x_{mn} \end{bmatrix} \quad i = \overline{0,m};\ j = \overline{1,n} \tag{4}$$

In Eq. 4, *m* illustrates the quantity of the options, and *n* represents the criteria. The value $\otimes x_{ij}$ shows the performance of the i^{th} option in the j^{th} criterion. The optimal value of the j^{th} criterion is *x_0j*. If the optimal value of the j^{th} variable is indeterminate, Eq. 5 determines a value for it:

$$\begin{aligned} \otimes x_{0j} &= \max_i \otimes x_{ij} \quad , if\ \max_i \otimes x_{ij} \quad is\ preferable \\ \otimes x_{0j} &= \min_i x_{ij}^* \quad , if\ \min_i x_{ij}^* \quad is\ preferable \end{aligned} \tag{5}$$

The decision-makers typically provide the decision matrix with the evaluation value of the options in the criterion ($\otimes x_{ij}$) and the weight of each criterion ($\otimes w_j$). It is noteworthy that the standards have different dimensions in the first step.

- In the second step, the initial input values for all criteria are normalized and become $\otimes \bar{x}_{ij}$, which are different components of the $\otimes \bar{X}$ matrix, as introduced below [54]:

$$\otimes\bar{X}=\begin{bmatrix}\otimes\bar{x}_{01} & \dots & \otimes\bar{x}_{0j} & \dots & \otimes\bar{x}_{0n}\\ \vdots & \ddots & \vdots & \ddots & \vdots\\ \otimes\bar{x}_{i1} & \dots & \otimes\bar{x}_{ij} & \dots & \otimes\bar{x}_{in}\\ \vdots & \ddots & \vdots & \ddots & \vdots\\ \otimes\bar{x}_{m1} & \dots & \otimes\bar{x}_{mj} & \dots & \otimes\bar{x}_{mn}\end{bmatrix} \qquad i=\overline{0,m};\ \ j=\overline{1,n} \tag{6}$$

As well, how the positive criteria are normalized is explained [55]:

$$\otimes\bar{x}_{ij}=\frac{\oplus x_{ij}}{\sum_{i=0}^{m}\otimes x_{ij}} \tag{7}$$

In addition, the negative criteria are normalized as follows [56]:

$$\otimes x_{ij}=\frac{1}{\otimes x_{ij}^{*}} \qquad \otimes\bar{x}_{ij}=\frac{\oplus x_{ij}}{\sum_{i=0}^{m}\otimes x_{ij}} \tag{8}$$

After making the criteria dimensionless, they can be compared to one another.

- The weights in the normalized matrix $\otimes\bar{X}$ are applied in the third step to obtain the $\otimes\hat{X}$ matrix. $\otimes w_j$ represents the weight of each criterion j^{th}. Of note, the weights are set by experts. The following conditions must be thus met by the given weights [57]:

$$0<\otimes w_j<1 \qquad \sum_{j=1}^{n} w_j=1 \tag{9}$$

$$\otimes\hat{X}=\begin{bmatrix}\otimes\hat{x}_{01} & \dots & \otimes\hat{x}_{0j} & \dots & \otimes\hat{x}_{0n}\\ \vdots & \ddots & \vdots & \ddots & \vdots\\ \otimes\hat{x}_{i1} & \dots & \otimes\hat{x}_{ij} & \dots & \otimes\hat{x}_{in}\\ \vdots & \ddots & \vdots & \ddots & \vdots\\ \otimes\hat{x}_{m1} & \dots & \otimes\hat{x}_{mj} & \dots & \otimes\hat{x}_{mn}\end{bmatrix} \qquad i=\overline{0,m};\ \ j=\overline{1,n} \tag{10}$$

$$\otimes\hat{x}_{ij}=\otimes\bar{x}_{ij}\times\otimes w_j; \qquad i=\overline{0,m} \tag{11}$$

wherein w_j shows the weight (importance) of the j^{th} criterion and $\bar{x}_{ij}$ is its normalized value. The value of the optimal function is given by the following expression [58]:

$$\otimes S_i=\sum_{j=1}^{n}\otimes\hat{x}_{ij}; \qquad i=\overline{0,m} \tag{12}$$

in which $\otimes S_i$ stands for the value of optimal function for option *i*. In addition, the best option is the one with the highest value and the worst is the one with the lowest value. The option order is determined by the value of $\otimes S_i$.

Gray fuzzy number $\otimes S_i$ is also the result of gray fuzzy decision-making. There are several ways to convert a gray fuzzy value into a specific one. The method of the region center is thus one of the most practical and simple methods, as discussed below [59].

$$S_i=\frac{1}{2}\left(S_{i\alpha}+S_{i\gamma}\right) \tag{13}$$

The application degree of each option is calculated by comparing it to the best value, known as S_0. The following is an explanation of the application degree equation, K_i, for option A_i [60]:

$$K_i=\frac{S_i}{S_0}; \qquad i=\overline{0,m} \tag{14}$$

where S_0 and S_i are calculated using Eq. 14. It is obvious that the value of K_i is between 0 and 1. All options are also prioritized according to their K_i

values. Figure 5 depicts the research steps based on the presented methodology.

5. Analysis

5.1. SWOT analysis

The SWOT analysis typically consists of two key steps [30]:

1. Creating a SWOT matrix, which contains listing the internal and external factors, such as strengths and weaknesses

In this sense the strengths and weaknesses as well as the opportunities and threats were identified through interviews with 11 experts in RE sources nd development, in addition to an investigation of the theoretical foundations. A semi-structured interview was further conducted; in this way, the problem in question was stated in general, and then the expert opinions and explanations were received and analyzed. Table 2 lists all factors relevant to RE development in Mazandaran Province, Iran.

2. Developing strategies based on the SWOT analysis

The weighting and ranking of the strategic factors at various levels was one of the research steps. In this regard, it is necessary to identify the weighted and prioritized criteria based on the factors identified at the levels of strength, weakness, opportunity, and threats.

There are also various approaches in studies evaluating the criteria of strengths and weaknesses as well as opportunities and threats. In some, strategic models, such as political, economic, sociological, technological, legal, and environmental (PESTLE) analysis, have been recruited to evaluate the factors at various levels. Following a review of the research literature, some experts in this field were interviewed. The final criteria identified to evaluate the factors at various levels were geographical, technological, economic, environmental, social, and safety-related in general.

Tab. 2. RE development strengths, weaknesses, opportunities, and threats in Mazandaran Province, Iran

Category	Index	Description
Strengths (S)	S01	Significant human capital in scientific, professional, and engineering fields
	S02	Sea and water sources
	S03	Suitable sunshine hours during the year
	S04	Good wind blowing in some areas during the year
	S05	Necessity of this issue in Iran’s upstream documents
	S06	Competition between RE sources and fossil fuels
	S07	Attention to knowledge-based employment in various fields including RE
	S08	Special attention to expansion of investment in RE in the Seventh Development Plan
	S09	Access to right and proper lands for RE plant construction
	S10	Interest and attention among scientific centers in the field of RE and its development
	S11	Existence of specialized organizations, such as SATBA, to implement RE projects
	S12	Specialized education and training in the field of RE at Iranian universities
Weaknesses (W)	W01	Life patterns and excessive consumption
	W02	Reduced investment in the private sector
	W03	Lack of attention to cooperation with the private sector
	W04	No clear roadmap for RE
	W05	Absence of coordination in various trustee and governmental organizations
	W06	Traditional views toward fossil fuel use
	W07	High initial investment costs of RE
	W08	Dependence of REs (especially solar energy) on climatic conditions and seasons
	W09	No value given by relevant institutions to elite ideas and abilities
Opportunities (O)	O01	Prices and affordability of RE sources
	O02	Reduction in the price of RE technologies
	O03	Capacity of RE sources in terms of economic development, employment, and value chain
	O04	RE industry development
	O05	Willingness of the private sector in terms of cooperation and partnership
	O06	Development of knowledge-based businesses in the field of RE sources
	O07	Development of public-private RE partnership projects
	O08	Use of World Bank facilities and international loans for RE
	O09	Iran’s commitment to reduce GHG emissions at the 2016 Paris Agreement

	O10	Creation of a suitable market for export and foreign exchange in Iran
Threats (T)	T01	Growing energy demand in Iran
	T02	Lack of public support for correcting consumption patterns
	T03	Absence of foreign investment due to sanctions
	T04	High risk of investment by allied countries in Iran
	T05	Government's focus on nuclear energy use and no attention to RE
	T06	Iran's huge oil and gas reserves
	T07	Subsidies allocated to fossil fuel sources
	T08	Approaches and views toward oil-based economy

5.2. Calculation of final weight of RE development criteria

Upon determining the research criteria, the weight of the indices was calculated step-by-step based on expert opinions, according to the SWARA method. Table 3 shows the outcome of the aforementioned process.

Tab. 3. Calculation of final weight of RE development criteria

Criterion	Average relative importance	K_j	Initial weight	Normal weight
Economy	1	1	1	0.24
Geography	0.05	1.06	0.94	0.23
Environment	0.19	1.19	0.8	0.19
Social welfare	0.27	1.27	0.62	0.15
Technology	0.4	1.32	0.48	0.11
Assurance & Safety	0.42	1.35	0.35	0.08
	Total		4.184	1.000

The SWARA method steps were computed in the same way to determine the weight of the sub-criteria. The weight of each criterion was multiplied by the weight of the sub-criteria to achieve the final weight, as presented in Table 4.

Tab. 4. Calculation of final weight of all sub-criteria of RE development

Criterion	Weight	Sub-criterion	Sub-criteria weight	Final weight
Economy (Eco)	0.24	Energy production costs (Eco1)	0.4	0.094
		Investment ability (Eco2)	0.37	0.088
		Research and development costs (Eco3)	0.24	0.058
Geography (Geo)	0.23	Suitable location (Geo1)	1	0.226
Environment (Env)	0.19	Emission reduction (Env1)	0.54	0.103
		Environmental disturbance (Env2)	0.46	0.087
Social welfare (S-W)	0.15	Improved people's energy welfare (S-W1)	0.53	0.079
		Job creation (S-W2)	0.48	0.070
Technology (Tec)	0.11	Source capacity (Tec1)	0.4	0.044
		Technical maturity (Tec2)	0.34	0.038
		Efficiency (Tec3)	0.28	0.030
Assurance & Safety (C-S)	0.08	Ensured results (A-S1)	0.52	0.043
		Operational safety (A-S2)	0.48	0.040

According to the results in Table 4, the most important criteria were appropriate location, pollution reduction, and energy production costs.

5.3. Prioritization of RE development strategies

The identified strategic factors were weighted after being identified and grouped into four categories of strengths, weaknesses, opportunities, and threats, and then evaluated.

In this regard, a questionnaire was designed for each category of the strategic factors, and the experts were asked to specify the weight of each one with verbal expressions related to gray fuzzy numbers according to Table 5 to obtain the final decision table for evaluating opportunities and threats as well as strengths and weaknesses in the form of gray fuzzy numbers with reference to Tables 6 to 9.

Tab. 5. Linguistic variables corresponding to gray fuzzy numbers

Linguistic variable	Gray fuzzy number
Very Low	(0 , 0.02)
Low	(0.1 , 0.3)
Medium low	(0.2 , 0.4)
Medium	(0.35 , 0.65)
Medium high	(0.6 , 0.8)
High	(0.7 , 0.9)
Very high	(0.8 , 1)

Tab. 6. Gray-ARAS final results for ranking and weighting strengths

Option	S gray	S	K	Rank
Optimal option	(0.054 , 0.068)	0.061	1.000	0
S01	(0.026 , 0.044)	0.035	0.574	11
S02	(0.040 , 0.058)	0.049	0.803	**2**
S03	(0.031 , 0.050)	0.040	0.655	9
S04	(0.035 , 0.051)	0.044	0.708	5
S05	(0.033 , 0.053)	0.043	0.704	6
S06	(0.035 , 0.050)	0.042	0.700	7
S07	(0.036 , 0.054)	0.045	0.735	3
S08	(0.034 , 0.053)	0.044	0.729	4
S09	(0.044 , 0.060)	0.052	0.900	**1**
S10	(0.022 , 0.038)	0.030	0.490	12
S11	(0.031 , 0.050)	0.040	0.663	8
S12	(0.028 , 0.045)	0.037	0.597	10

Tab. 7. Gray-ARAS final results for ranking and weighting weaknesses

Option	S gray	S	K	Rank
Optimal option	(0.069 , 0.089)	0.079	1.000	0
W01	(0.047 , 0.072)	0.059	0.75	3
W02	(0.040 , 0.068)	0.053	0.679	6
W03	(0.039 , 0.064)	0.052	0.655	8
W04	(0.044 , 0.070)	0.057	0.723	4
W05	(0.031 , 0.057)	0.044	0.561	9
W06	(0.054 , 0.077)	0.066	0.834	**1**
W07	(0.042 , 0.070)	0.056	0.713	5
W08	(0.047 , 0.071)	0.059	0.745	**2**
W09	(0.041 , 0.065)	0.053	0.67	7

Tab. 8. Gray-ARAS final results for ranking and weighting opportunities

Option	S gray	S	K	Rank
Optimal option	(0.059 , 0.075)	0.068	1.000	0
O01	(0.039 , 0.062)	0.050	0.755	5
O02	(0.043 , 0.064)	0.053	0.800	4
O03	(0.034 , 0.054)	0.044	0.661	9
O04	(0.036 , 0.059)	0.048	0.713	8
O05	(0.046 , 0.066)	0.057	0.840	**1**
O06	(0.043 , 0.062)	0.052	0.780	3

O07	(0.038 , 0.060)	0.049	0.728	7
O08	(0.034 , 0.054)	0.044	0.652	10
O09	(0.041 , 0.059)	0.050	0.750	6
O10	(0.042 , 0.063)	0.053	0.783	**2**

Tab. 9. Gray-ARAS final results for ranking and weighting threats

Option	S gray	S	K	Rank
Optimal option	(0.070 , 0.091)	0.080	1.000	0
T01	(0.059 , 0.084)	0.072	0.900	**1**
T02	(0.049 , 0.072)	0.060	0.750	5
T03	(0.052 , 0.080)	0.066	0.820	3
T04	(0.043 , 0.073)	0.058	0.720	7
T05	(0.053 , 0.076)	0.065	0.804	4
T06	(0.057 , 0.079)	0.066	0.823	**2**
T07	(0.042 , 0.068)	0.054	0.676	8
T08	(0.044 , 0.074)	0.059	0.734	6

Table 10 summarizes the results of prioritizing the strategies of opportunities and threats as well as strengths and weaknesses using the Gray-ARAS method.

Tab. 10. Prioritization of RE development strategies in Mazandaran Province, Iran, based on strengths, weaknesses, opportunities, and threats

		Strategic factors selected at the levels of strengths, weaknesses, opportunities, and threats
Strengths	S09	Access to right and proper lands for the construction of RE plants
	S02	Sea and water sources
Weaknesses	W06	Traditional views toward fossil fuel use
	W08	Dependence of RE (especially solar energy) on climatic conditions and seasons
Opportunities	O05	Willingness of the private sector for cooperation and partnership
	O10	Creation of a suitable market for export and foreign exchange in Iran
Threats	T01	Growing energy demand in Iran
	T06	Iran's huge oil and gas reserves

5.4. Validation

The Gray-WASPAS method was used to assess the rankings of the strategic variables of strengths, weaknesses, opportunities, as well as threats. Afterward, the results were evaluated using Spearman's rank correlation coefficient, and compared with those of other approaches [61].

$$rs = 1 - \frac{6\sum_i di^2}{n^3 - n} \tag{15}$$

In this regard, *di* represents the difference in the ranking of the strategic factors in the Gray-ARAS technique and other methods, and *n* indicates the quantity of the compared ranks.

5.4.1. Evaluation of results for ranking purposes

The findings with regard to the ranking of the strengths using the Gray-ARAS technique were contrasted to those obtained from the Gray-WASPAS method, as listed in Tables 11 to 14

.

Tab. 11. Comparison of final rankings of strengths

Strengths	Gray-ARAS	Gray-WASPAS
S01	11	11
S02	2	2
S03	9	9
S04	5	6
S05	6	5
S06	7	7

S07	3	3
S08	4	4
S09	1	1
S10	12	12
S11	8	8
S12	10	10
Spearman's rank correlation coefficient (Strengths)	0.99	

Tab. 12. Comparison of final rankings of weaknesses

Weaknesses	Gray-ARAS	Gray-WASPAS
W01	3	3
W02	6	6
W03	8	8
W04	4	4
W05	9	9
W06	1	1
W07	5	5
W08	2	2
W09	7	7
Spearman's rank correlation coefficient (Weaknesses)	1.00	

Tab. 13. Comparison of final rankings of opportunities

Opportunities	Gray-ARAS	Gray-WASPAS
O01	5	5
O02	4	2
O03	9	9
O04	8	8
O05	1	1
O06	3	4
O07	7	6
O08	10	10
O09	6	7
O10	2	3
Spearman's rank correlation coefficient (Opportunities)	0.95	

Tab. 14: Comparison of final rankings of threats

Threats	Gray-ARAS	Gray-WASPAS
T01	1	1
T02	5	5
T03	3	2
T04	7	7
T05	4	4
T06	2	3
T07	8	8
T08	6	6
Spearman's rank	0.98	

correlation coefficient (Threats)	

6. Discussion and Conclusion

RE, such as solar, wind, and wave energy, are critical to achieve rapid decarbonization and limit global warming by replacing fossil fuels. However, the lack of knowledge about the potentials, feasibility, evaluation, and location of RE sources in developing countries is a barrier to enacting adequate policies to promote them. Furthermore, the optimal use of RE sources necessitates strategic decision-making to reduce pollution, exploit conventional sources, and improve economic development. Environmental, economic, social, and technological requirements are all important considerations when evaluating RE sources. Furthermore, a wide variety of factors influence the selection of suitable RE sources, which rely on uncertain and imprecise data. As a result, this selection procedure can be thought of as a complex MCDM problem.

Reviewing previous studies revealed that the most part of the literature in the field of determining RE development strategies had only recruited the SWOT analysis, but the suggested factors along with the main strategies had not been prioritized, although the environmental factors had been examined qualitatively. To deal with the weaknesses of the SWOT analysis, the MCDM techniques with a range of gray fuzzy numbers were employed in this study to account for the uncertainty of linguistic variables in the real world. According to the SWOT analysis and the SWARA method results, among the factors affecting RE in Mazandaran Province, Iran, the economic criterion, with the final weight of 0.24, was ranked first; and then the geographical and environmental criteria, having the final weights of 0.23 and 0.19, were put in the second and third places, respectively. In this regard, appropriate location, with the final weight of 0.226, was ranked first; and subsequently pollution reduction and energy production costs, receiving the final weights of 0.103 and 0.094, were the second and third sub-criteria, respectively. The findings revealed access to right and proper lands for the construction of RE power plants, as well as sea and water sources (at the level of threats), traditional views toward fossil fuel use and dependence of RE (particularly solar energy) on climatic conditions and seasons (at the level of weaknesses), willingness of the private sector for cooperation and partnership and creation of a suitable market for export and foreign exchange in Iran (at the level of opportunities), as well as growing energy demand and Iran’s vast oil and gas reserves (at the level of strengths), as the most important strategies for RE development in Mazandaran Province, Iran. According to the study findings, the following recommendations were provided:

- Power plants should be constructed as close to the energy sources as possible. Transmission costs and losses are thus reduced. Notably, hydroelectric power plants cannot be located near load centers, but they require transmission lines that are longer, shorter, or medium in length. This necessitates more investment. In this regard, the authorities in the RE industry in Mazandaran Province, Iran, are suggested to attract more funds through companies in order to reduce the existing risks because this region has many marine and water sources.
- In line with the construction of hydropower plants, it is recommended to take account of future climate policies and regional electricity demands when planning for the RE development and the related industry. Furthermore, there is a need to reflect on climatic conditions and sea and water sources as well as suitable sunshine hours during the year. Therefore, hydro and solar power plants should be built simultaneously.
- Considering the appropriateness of the daily sunshine hours in this region, officials are suggested to care about the location of houses and the slope of their roofs, installation costs, project duration, and durability of solar systems when constructing solar power plants.
- Researchers should use the Data Coverage Analysis technique to assess the efficiency of RE-based companies in

order to expand this industry as much as possible.

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