An intelligent multi-criteria decision-based approach for sustainable growth of the energy sector: the case study of India and Vietnam

Vishal Srivastava[*1], Saurabh bhardwaj [2], Gopal Chaudhary[3]

[1] VIPS-TC, School of Engineering & Technology, New Delhi, India
[2] Thapar Institute of Engineering & Technology, Patiala, India
[3] VIPS-TC, School of Engineering & Technology, New Delhi, India
Emails: vishal.srivastava@vips.edu; saurabh.bhardwaj@thapar.edu; gopal@vips.edu

Abstract

Traditional and sustainable forms of energy are examined from a variety of angles, including economics, technology, society, ecology, politics, and flexibility, to ensure that Vietnam's energy industry continues to expand sustainably. These sources have been evaluated and assessed using an extended spherical fuzzy MCDM method. Thermal, gas, nuclear, solar, wind, biomass, and hydro energy alternatives are employed in the decision-making model. The weights of evaluation criteria are determined using the spherical fuzzy AHP model, and renewable power choices are prioritized using the WPM model. We used six main criteria, twenty-six sub-criteria, and seven alternatives. In Vietnam, solar power was found to be the most suitable, followed by wind and hydropower, followed by hydro, followed by Biomass. The worst alternative is thermal. After that, fourteen situations were built, taking into consideration the first five renewable technologies (solar, wind, hydro, biomass, and gas power), in assessing the ideal energy mix scenario for the slow gestation of Vietnam's energy sector. Solar, wind, and hydro energy growth in a pass shipping scenario.

Keywords: Multi criteria decision making; Compromise solution; Renewable energy; Spherical fuzzy; AHP; WPM; Mining method selection

1. Introduction

The importance of sustainable growth for the well-being of the community and the country has grown. Defined sustainable development as growth that serves the requirements of the current era without affecting the capabilities of a better future [1]–[4]. Energy is an important component of any government's long-term peace and growth in the contemporary age. Growth and development, population expansion, and remarkable wealth creation have led to an increase in energy usage in the country during the previous several years.

A record of 809.2 million tonnes per annum was produced in 2018 [5]. In terms of electricity production, coal accounts for 55%, petroleum products for 29%, fossil fuel for 6%, nuclear energy for 2%, hydro for 4%, and energy production for 4%.

The mean production between 1997 and 2018 was 6.51 percent, whereas the energy usage rate was 6.53 percent [6]. The nation's industrial growth is heavily reliant on its energy usage [7].

India is always dealing with a lack of energy, both in the form of foundation power and maximum electricity. The year 2014-15 had a 5% foundation energy shortage and a 2% highest power shortfall. Energy shortages in the nation hampered the country's industrial and agricultural

DOI: https://doi.org/10.54216/JISIoT.060105
Received: January 15, 2022 Accepted: March 08, 2022

expansion [8]. India relies heavily on fossil fuels for its energy production, with a 70% stake in the whole annual production of India [9]. The Indian economy is burdened by the importation of these fossil fuels from nations like South Africa, Indonesia, and, Australia [10]. Fossil fuel consumption exacerbates the already-serious issue of global warming-causing greenhouse gas emissions. After China and the United States, Hinduism is the third source of greenhouse gas emissions [6], [11].

A broad energy plan and an increase in renewable and sustainable sources of energy are necessary for the nation. It's important to find an answer that is expensive, efficient, dependable, less hazardous to nature and human health has little waste and is long-term[12]–[14]. Multiple competing criteria make it difficult to identify and pick the most acceptable renewable power source. Economic, environmental, and social aspects of sustainability were highlighted during the United Nations World Summit in 2002[15]. When making decisions in the previous decade, different factors including organizational and technological ones have been considered [16], [17]. So in this research, numerous aspects, such as economic and social as well as economic and legal are taken into account while evaluating both based on renewable sources of electricity. Multi-criteria decision-making (MCDM) has been implemented using integrated spherical fuzzy MCDM methods.

The main goal of the paper:

I. Analyze potential power sources for India's future growth.
II. To compare and validate the results using a variety of combined MCDM methodologies.
III. To determine the best possible fuel mix for India's long-term growth.

The spherical fuzzy AHP technique integrated with WPM is used to assess sustainable energy sources.

Here are the sections of the paper: The structure and prospects of the Indian energy sector are discussed in Section 2. A decision model including objectives, criteria, sub-criteria, and options is discussed in Section 3. Section 4 proposed the application and results. Section 5 provides the conclusion of the paper.

2. Structure of energy

India's electricity industry relies heavily on thermal electrical grids. India's installed nuclear power capacity is 60 percent of the country's total installed capacity, making it a significant power source. Fuel is burned in a thermal power plant to produce heat or energy, which may then be used. Chemical generating units use a variety of fuels including coal, gas, and oil to generate electricity. There is still no substitute for coal as the primary source of energy in Indian thermal power stations. There are 205324 MW in total capacity, which is 55.39 percent of the total generation capacity. As a reliable, low-cost, and generally available fuel source, coal is often employed in thermal power plants. It's no secret that India is one of the world's top two coal producers. At 716 MT in 2017, India accounted for 9.3 percent of global coal output. Coal reserves in India are the world's fifth-largest (98 billion tonnes)[18]. In common with other fossil fuels, coal also includes large levels of carbon, sulfur, and nitrogen. Issues like acid rain and climate change will be exacerbated.

Natural gas is a highly efficient, environmentally friendly, and cost-effective energy source. Using natural gas as a fuel, oil and gas make energy. Natural gas reserves in India are expected to reach 1227.23 trillion cubic meters by 2016, according to current estimates. Eastern undersea had 36.79 percent of the world's natural gas resources, while western offshore held 23.95 percent [19]. With reduced gestation time and higher thermodynamic performance, natural gas-fired power plants are more efficient than other types of plants. It can also ratchet up and drop down quickly, allowing it to assist meet peak demand. High thermodynamic efficiency is a hallmark of modern gas and steam power plants. Hydrogen, hydrosulfide, oxygen, and heavier alkanes are all present in natural gas. This means that when natural gas is burned, there is a significant release of carbon dioxide, nitrous oxide, and hydrogen sulfide[20].

This alternative energy is derived from the sun's rays and may be used again and over. With the help of a solar water heating system or photovoltaic solar cells, the sun's rays may be transformed into usable energy. Latitude and longitude as well as seasons, height, moisture content, and weather reports all affect how much solar energy is absorbed by the Ground atmosphere [21]. India is fortunate in that it is situated between both the Tropic of Cancer and the Equator. As a result, India gets between 1200 and 2300 kWh/m2/year of global solar radiation [22]. Renewable power potential

DOI: https://doi.org/10.54216/JISIoT.060105
Received: January 15, 2022 Accepted: March 08, 2022

in India is the biggest in the world, with an estimated 750 GW[23]. The Jammu & Kashmir state has an accessible power capacity of 111 GW, whereas Rajasthan has 142 GW of solar energy potential[24].

The Jawaharlal Nehru National Sun Mission [JNNSM] involves boosting solar energy production. As part of the Part Of Climate Change (NAPCC), the Indian National Solar Mission (JNNSM) launched solar energy generation in 2010. There's an ambitious 20 GW map solar power objective, and 2 GW off the grid, which includes 20 million solar artificial lighting until 2022, under the JNNSM[25]. However, arsenic and arsenic are used in the manufacturing of a photovoltaic array, which is regarded to be one of the most environmentally friendly methods of generating electricity[26].

Wind power is very well technologically, as well as the most environmentally friendly and economically viable. Because of this, it is considered fossil fuels. Wonky warming on the Planet's surface causes airflow. Wind turbines are used to convert the energy of moving air into renewable electricity. Offshore wind potential in India was assessed in 2012 at 49.13 gigawatts (GW) by the Central Institute of Offshore Wind (NIWE). IWTMA and WISE, the Indian Wind Farm Manufacturing Organization, and the World Institute for Renewable Energy, respectively, but the wind energy potential is at 65–70 GW. According to recent research, India has the potential to generate 213.44 GW of potential offshore wind in a territory that is very appropriate (Rank 1) [29]. However, another recent research evaluated the overall wind power potential by area, such as the eastern region 155 GW, the west 914 GW, the northern region 397 GW, the southern region 1265 GW, and the north-eastern region 8 GW. Currently, India ranks sixth in the world when it comes to installed wind energy capacity. Wind energy production. Seven hundred and forty-four specialized wind control points have been erected at various altitudes of 20 m to 120 m to determine the wind potential. Until 2022, the Indian government has set an ambitious goal of installing 175 GW of renewable energy capacity. A total of 100 GW of solar energy, 60 GW of wind energy, 10 GW of hydroelectricity, and 5 GW of biomass power will be required to meet this goal. Wind turbines emit noise pollution as an environmental consequence. Noise levels of 50–60 decibels (dB) are generated by one wind farm at a distance of 40 meters [27]–[31].

A hydroelectric power plant utilizes the energy of flowing water to produce electricity. When India's first hydroelectric power station, in Darjeeling, was put into service in 1879, it had a 130-kW capacity. An estimated 84044 MW of hydroelectric power potential is available in India with a 60% plant load factor. Hydroelectric power facilities in India are being developed by public sector institutions. Water-based power generation has the benefit of being fast to respond to spikes in demand, easy to start/stop, and able to store energy for daily, seasonal, and peak load demands. There was a long gestation time for hydroelectric power installations, which necessitated large capital expenditures. Hydraulic power plants produce less $CO2$ and other greenhouse gases, as well as fewer NO_x and SO_x emissions than other types of power plants. Social and environmental systems are disrupted as a result of changes in agricultural and irrigation patterns, the purchase of land for rehabilitation, and the resettlement of people.

There are abundant biomass supplies in the production of food waste, animal dung, and organic components present in urban and industrial garbage that may be used to produce biofuels. You may use a variety of different methods to turn biomass into a source of energy that is useful. Agricultural wastes (17538 megawatts), bagasse cogeneration (5000 megawatts), (and 2556 megawatts) all contribute to India's enormous biomass power potential. Biomass energy produces greenhouse gases and a small quantity of NO_x and SO_x, which have a detrimental environmental impact.

The energy generated when an organism's nucleus is divided or merged is known as nuclear energy. Thermal, renewable, and hydroelectric power are India's top three energy sources, with nuclear power coming in at number four. There are 6780 MW of nuclear power plants in operation today, which accounts for around 2% of the total installed capacity. An increase in installed capacity of 5300 MW is planned. Nuclear power facilities in India are built, operated, and maintained by a government-owned company. Controversial: Nuclear power generates a lot of heat. Radioactive waste from nuclear power is a major worry for many organizations, citizens, environmentalists, and socialists. Nuclear power is not widely accepted in India because the public mistrusts nuclear power and the dangers of its toxic fuel.

DOI: https://doi.org/10.54216/JISIoT.060105
Received: January 15, 2022 Accepted: March 08, 2022

3. Spherical Fuzzy AHP % WPM Methods

Because it fails to account for human judgments' inherent ambiguity, the stochastic AHP technique has come under fire [32]. SFS, a unique variation of AHP, was employed in this work to address the limitations of AHP, namely, the inability to capture the indeterminacy of information, which is one of the main drawbacks of this methodology. When applied to wider domains, SFS's definition of a membership value on a spherical surface allows the coefficients of the function to be assigned separately for different forms of uncertainty [33], [34]. Between zero and one may be found in SFS's squared sum of participation, non-membership, and hesitation. In addition, each one may be projected to a domain individually to ensure that their squared total is no more than 1. SFSs are discussed in the next section. More information about SFSs may be found at [34]. Figure 1 shows the proposed methodology.

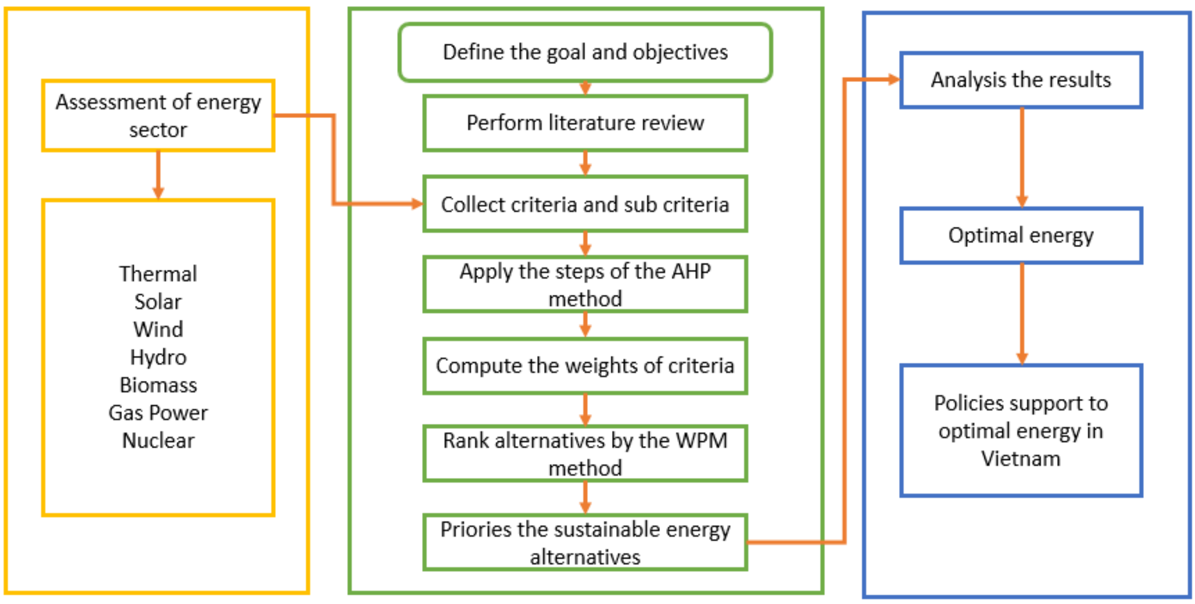

Figure 1: The proposed framework of this paper.

Addition

$$A_s \oplus B_s = \left\{ \begin{array}{c} \sqrt{e^2{}_{A_s} + e^2{}_{B_s} - e^2{}_{A_s}.e^2{}_{B_s}}, f_{A_s}.f_{B_s} \\ \sqrt{((1-e^2{}_{B_s})g^2{}_{A_s} + (1-e^2{}_{A_s})g^2{}_{B_s} - g^2{}_{A_s}.g^2{}_{B_s})} \end{array} \right\}$$

$$A_s \otimes B_s = \left\{ \begin{array}{c} f_{A_s}.f_{B_s}, \sqrt{f^2{}_{A_s} + f^2{}_{B_s} - f^2{}_{A_s}.f^2{}_{B_s}} \\ \sqrt{(1-e^2{}_{B_s})g^2{}_{A_s} + (1-f^2{}_{A_s})g^2{}_{B_s} - g^2{}_{A_s}.g^2{}_{B_s}} \end{array} \right\}$$

$$x.A_s = \left\{ \begin{array}{c} \sqrt{1-(1-e^2{}_{A_s})^x} \\ f^x{}_{A_s} \\ \sqrt{(1-e^2{}_{A_s})^x - (1-e^2{}_{A_s} - g^2{}_{A_s})^2} \end{array} \right\}$$

$$A_s{}^x = \left\{ \begin{array}{c} e^x{}_{A_s}, \sqrt{1-\left(1-f^2{}_{A_s}\right)^x}, \\ \sqrt{1-\left(1-f^2{}_{A_s}\right)^x - \left(1-f^2{}_{A_s} - g^2{}_{A_s}\right)^x} \end{array} \right\}$$

DOI: https://doi.org/10.54216/JISIoT.060105
Received: January 15, 2022 Accepted: March 08, 2022

Step 1: Defining the deliverables for the perfection of airports is the first step in the process. A comparison matrix is formed using the language variables in [35]

Step 2: Score index (SC) is then calculated using

$$SC = \sqrt{\left|100 \times \left(\left(e^2{}_{A_s} - g^2{}_{A_s}\right)^2 - \left(f^2{}_{A_s} - g^2{}_{A_s}\right)^2\right)\right|}$$

$$SC^{-1} = \frac{1}{\sqrt{\left|100 \times \left(\left(e^2{}_{A_s} - g^2{}_{A_s}\right)^2 - \left(f^2{}_{A_s} - g^2{}_{A_s}\right)^2\right)\right|}}$$

Step 3: Aggregate the comparison matrix by the average method

Step 4: Test the consistency ratio to validate the opinions of experts

Step 5: Normalize the comparison matrix

Step 6: Calculate the weights of the criteria

Step 7: Compute the weights of sub-criteria

Step 8: Compute the global weights by multiplying the weights of local weights by the global weights

Step 9: Rank the alternatives by the WPM method as

The weighted product technique is just as basic and straightforward as the WSM method. This sub-power criterion of weights is calculated by calculating the performance value of the alternative sub-criterion. The preferred score option may be calculated by multiplying the weighted normalized values of every energy alternative. Those with a prominent " rating will be offered a prominent place in the results.

Step 9.1 Build the decision matrix by the opinions of experts

Step 9.2: Aggregate the opinions of experts

Step 9.3 Compute the value of the WPM method as

$$A_i^{WPM} = \prod_{j=1}^{n} x_{ij}^{w}$$

$Where\ i = 1,2,3, n;\ (criteria)\ j = 1,2,3, m\ (alternatives)$

Step 9.4 Rank alternatives by the highest value of A_i^{WPM}

4. Findings based on data sets

The study's objectives are to:

I. examine Vietnam's energy sources; and
II. establish the country's ideal energy mixture situation for the country's environmental sustainability. 'Results and Analysis' is thus divided into two parts to illustrate the two-fold goals of this section, which are briefly explained below.

We used six main criteria and twenty-six criteria. The seven alternatives are used in this paper as below:

DOI: https://doi.org/10.54216/JISIoT.060105
Received: January 15, 2022 Accepted: March 08, 2022

Main criteria	Sub criteria	Alternatives
Economic	Capital Cost/Investment Cost EESC1	Biomass EEA1
	Operation & Maintenance Cost EESC2	Thermal EEA2
	Payback period EESC3	Gas power EEA3
	Levelized Cost of Electricity EESC4	Wind EEA4
	Useful/operational Life EESC5	Solar EEA5
	Fuel Cost EESC6	Nuclear EEA6
	Availability of Funds/Incentives EESC7	Hydro EEA7
Technical	Technology Maturity EESC8	
	Efficiency EESC9	
	Capacity Factor EESC10	
	Reliability EESC11	
	Deployment Time EESC12	
Environment	Environmental Land requirement EESC13	
	Pollutant Emission EESC14	
	Impact on ecosystem EESC15	
	Climate change EESC16	
Political	Political acceptance EESC17	
	Foreign dependency EESC18	
	Compatibility with national energy policy EESC19	
	Fuel reserve years EESC20	
Social	Social benefits EESC21	
	Job creation EESC22	
	Social acceptance EESC23	
	Impact on human health EESC24	
Flexibility	In integration with another source EESC25	
	In fulfilling the peak load demand EESC26	

Two parts make up this section: criterion weights derived from spherical fuzzy AHP, and the fuzzy WPM technique used to rank alternatives. The first three experts evaluate the main and sub-criteria. The comparison matrix by three experts between the main criteria in Tables 1-3. Then the aggregated comparison matrix is in table 4. Then the normalized comparison matrix is in table 5.

Based on the spherical fuzzy AHP method, the economic and technical factors are the most significant criterion, with a relative weight of 0.529272 and 0.19659 for each. In terms of importance, the environment criteria come in third place, earning a preferred score of 0.1334. The three least significant elements are: political, societal, and adaptability of the solution by 0.081524, 0.042818, and 0.016449. Figure 2. Show the weights of the main criteria.

Table 1: The comparison matrix value by the first expert

	EEC_1	EEC_2	EEC_3	EEC_4	EEC_5	EEC_6
EEC_1	1	19.99994	23.5	5.491812	23.5	5.491812

DOI: https://doi.org/10.54216/JISIoT.060105
Received: January 15, 2022 Accepted: March 08, 2022

EEC_2	0.05	1	10.5	7.998594	5.491812	19.99994
EEC_3	0.042553	0.095238	1	23.5	23.5	23.5
EEC_4	0.182089	0.125022	0.042553	1	19.99994	7.998594
EEC_5	0.042553	0.182089	0.042553	0.05	1	19.99994
EEC_6	0.182089	0.05	0.042553	0.125022	0.05	1

Table 2: The comparison matrix value by the second expert

	EEC_1	EEC_2	EEC_3	EEC_4	EEC_5	EEC_6
EEC_1	1	19.99994	5.491812	23.5	19.99994	19.99994
EEC_2	0.05	1	23.5	5.491812	2.966058	2.966058
EEC_3	0.182089	0.042553	1	23.5	19.99994	2.966058
EEC_4	0.042553	0.182089	0.042553	1	2.966058	26.99995
EEC_5	0.05	0.337148	0.05	0.337148	1	19.99994
EEC_6	0.05	0.337148	0.337148	0.037037	0.05	1

DOI: https://doi.org/10.54216/JISIoT.060105
Received: January 15, 2022 Accepted: March 08, 2022

Table 3: The comparison matrix value by the third expert

	EEC_1	EEC_2	EEC_3	EEC_4	EEC_5	EEC_6
EEC_1	1	5.491812	26.99995	26.99995	26.99995	26.99995
EEC_2	0.182089	1	5.491812	5.491812	7.998594	5.491812
EEC_3	0.037037	0.182089	1	26.99995	26.99995	26.99995
EEC_4	0.037037	0.182089	0.037037	1	7.998594	19.99994
EEC_5	0.037037	0.125022	0.037037	0.125022	1	5.491812
EEC_6	0.037037	0.182089	0.037037	0.05	0.182089	1

Table 4: The aggregated comparison matrix

	EEC_1	EEC_2	EEC_3	EEC_4	EEC_5	EEC_6
EEC_1	1.00	15.16	18.66	18.66	23.50	17.50
EEC_2	0.09	1.00	13.16	6.33	5.49	9.49
EEC_3	0.09	0.11	1.00	24.67	23.50	17.82
EEC_4	0.09	0.16	0.04	1.00	10.32	18.33
EEC_5	0.04	0.21	0.04	0.17	1.00	15.16

DOI: https://doi.org/10.54216/JISIoT.060105
Received: January 15, 2022 Accepted: March 08, 2022

EEC_6	0.09	0.19	0.14	0.07	0.09	1.00

Table 5: The normalized comparison matrix

	EEC_1	EEC_2	EEC_3	EEC_4	EEC_5	EEC_6
EEC_1	0.713578	0.900571	0.564706	0.366683	0.367756	0.220641
EEC_2	0.067098	0.059389	0.398295	0.124312	0.085844	0.119618
EEC_3	0.062243	0.006332	0.030257	0.484616	0.367756	0.224736
EEC_4	0.062243	0.009684	0.001232	0.019647	0.161524	0.231178
EEC_5	0.030824	0.012754	0.001307	0.003354	0.015649	0.191217
EEC_6	0.064014	0.011269	0.004203	0.001389	0.001471	0.01261

DOI: https://doi.org/10.54216/JISIoT.060105
Received: January 15, 2022 Accepted: March 08, 2022

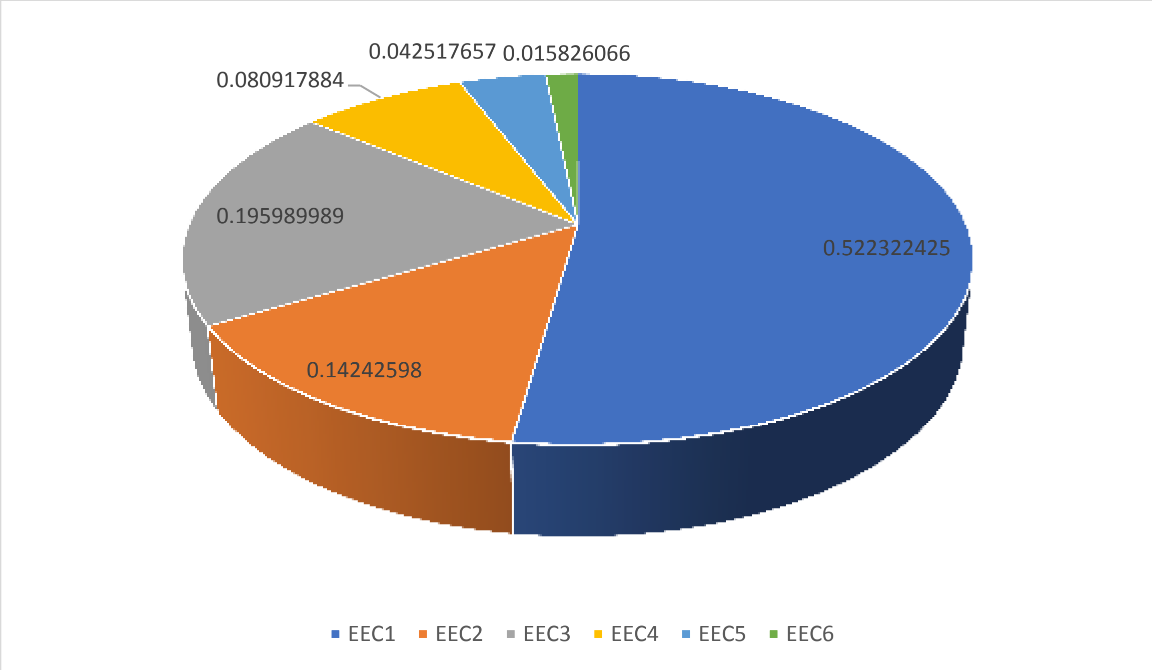

Figure 2: The weights of the main criteria.

$EESC_1$, $EESC_2$, and $EESC_{12}$ are three of the most essential sub-criteria for sustainability evaluation, as seen in Figure 3.

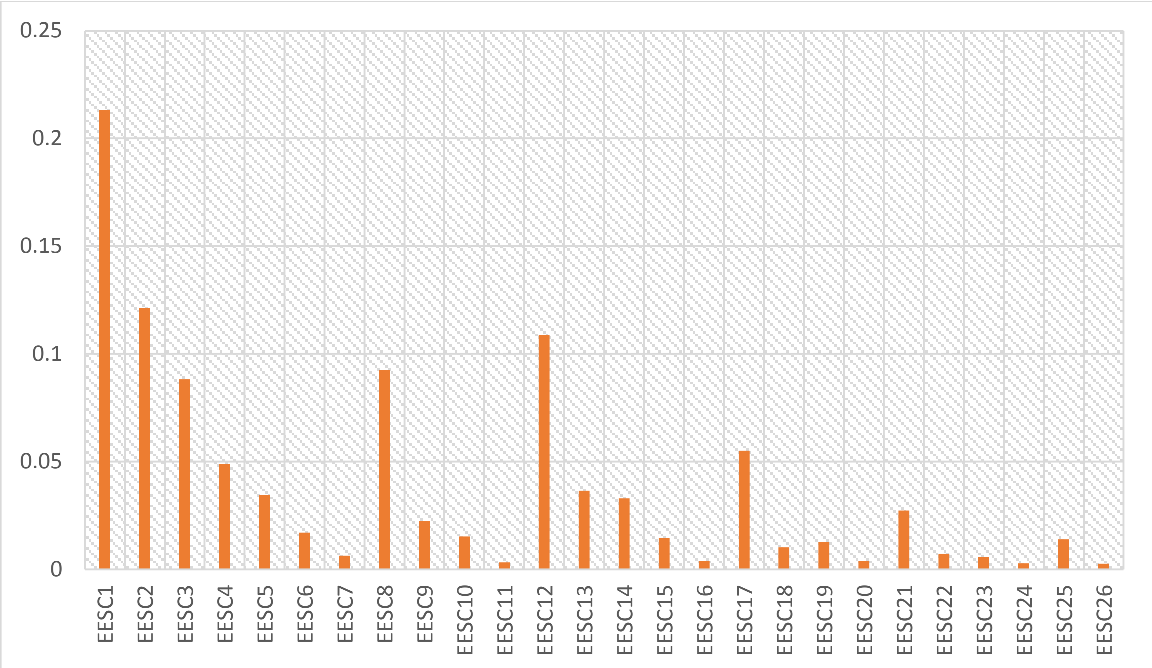

Figure 3: The weights of global weights

The energy options are ranked using the spherical fuzzy WPM method, which uses weights based on spherical fuzzy AHP. For each criterion, the energy alternatives are compared pairwise to get the preference ratings for the various energy options. Tables 6-8 show the decision matrix evaluated by the three experts. Table 9 shows the aggregated decision matrix. Table 10. Show the values of the WPM method. Solar and wind are the highest ranks in this study and nuclear and thermal are the lowest rank. Figure 4 shows the rank of alternatives.

DOI: https://doi.org/10.54216/JISIoT.060105
Received: January 15, 2022 Accepted: March 08, 2022

Table 6: The decision matrix by the first expert.

	EEA_1	EEA_2	EEA_3	EEA_4	EEA_5	EEA_6	EEA_7
EES	594	594	994	23.5	994	594	994
EES	995	23.5	058	23.5	594	594	594
EES	594	594	594	23.5	23.5	594	23.5
EES	594	995	23.5	594	23.5	594	23.5
EES	594	058	594	058	23.5	994	994
EES	594	058	23.5	994	23.5	994	23.5
EES	23.5	594	058	23.5	594	23.5	594
EES	23.5	594	594	594	995	23.5	594
EES	23.5	058	058	594	23.5	594	994
EES	058	058	594	994	995	23.5	058
EES	23.5	594	594	058	058	23.5	594
EES	23.5	058	058	23.5	23.5	23.5	994
EES	23.5	594	058	23.5	594	058	994
EES	23.5	058	594	994	23.5	594	995
EES	058	594	058	23.5	594	995	23.5
EES	058	058	594	594	995	23.5	058
EES	23.5	994	058	994	594	058	994
EES	995	23.5	058	23.5	594	23.5	594
EES	812	812	594	594	594	812	812
EES	058	058	058	23.5	594	995	23.5
EES	23.5	058	058	994	23.5	594	994
EES	594	812	058	23.5	594	23.5	594
EES	23.5	058	594	594	23.5	594	995
EES	812	812	812	23.5	594	995	23.5
EES	594	058	594	23.5	594	23.5	594
EES	23.5	23.5	594	23.5	058	23.5	23.5

Table 7: The decision matrix by the second expert.

	EEA_1	EEA_2
EES	594	594
EES	995	23.5
EES	594	594
EES	594	995
EES	594	058
EES	594	058
EES	23.5	594
EES	23.5	594
EES	23.5	058
EES	058	058
EES	23.5	594
EES	23.5	058
EES	23.5	594
EES	23.5	058
EES	058	594
EES	058	058
EES	23.5	994
EES	995	23.5
EES	812	812
EES	058	058
EES	23.5	058
EES	594	812
EES	23.5	058
EES	812	812
EES	594	058
EES	594	594

DOI: https://doi.org/10.54216/JISIoT.060105
Received: January 15, 2022 Accepted: March 08, 2022

EEA_7	EEA_6	EEA_5	EEA_4	EEA_3
23.5	594	594	23.5	23.5
23.5	594	995	23.5	23.5
	594	594		
594	594	594	594	594
058	994	594	058	058
994	994	594	994	994
23.5	23.5	23.5	23.5	23.5
594	23.5	23.5	594	594
594	594	23.5	594	594
594	23.5	058	594	594
058	23.5	23.5	058	058
23.5	23.5	23.5	23.5	23.5
23.5	058	23.5	23.5	23.5
594	594	23.5	594	594
23.5	995	058	23.5	23.5
594	23.5	058	594	594
23.5	058	23.5	23.5	23.5
23.5	23.5	995	23.5	23.5
594	812	812	594	594
23.5	995	058	23.5	23.5
594	594	23.5	594	594
23.5	23.5	594	23.5	23.5
594	594	23.5	594	594
23.5	995	812	23.5	23.5
23.5	23.5	594	23.5	23.5
594	812	594	594	594

Table 8: The decision matrix by the third expert.

EEA_5	EEA_4	EEA_3	EEA_2	EEA_1	
5.491812	23.5	7.998594	5.491812	23.5	EES
23.5	23.5	2.966058	23.5	23.5	EES
23.5	7.998594	23.5	23.5	7.998594	EES
23.5	7.998594	23.5	23.5	7.998594	EES
2.966058	2.966058	2.966058	2.966058	2.966058	EES
19.99994	19.99994	23.5	19.99994	19.99994	EES
19.99994	23.5	19.99994	19.99994	23.5	EES
23.5	7.998594	23.5	23.5	7.998594	EES
19.99994	7.998594	23.5	19.99994	7.998594	EES
23.5	7.998594	23.5	23.5	7.998594	EES
7.998594	2.966058	19.99994	7.998594	2.966058	EES
7.998594	23.5	7.998594	7.998594	23.5	EES
19.99994	23.5	19.99994	19.99994	23.5	EES
7.998594	7.998594	23.5	7.998594	7.998594	EES
19.99994	23.5	7.998594	19.99994	23.5	EES
23.5	7.998594	23.5	23.5	7.998594	EES
7.998594	23.5	19.99994	7.998594	23.5	EES
19.99994	23.5	5.491812	19.99994	23.5	EES
23.5	7.998594	23.5	23.5	7.998594	EES
5.491812	23.5	7.998594	5.491812	23.5	EES
23.5	7.998594	23.5	23.5	7.998594	EES
23.5	23.5	5.491812	23.5	23.5	EES
23.5	7.998594	23.5	23.5	7.998594	EES
5.491812	23.5	7.998594	5.491812	23.5	EES
7.998594	23.5	23.5	7.998594	23.5	EES
23.5	5.491812	5.491812	5.491812	5.491812	EES

DOI: https://doi.org/10.54216/JISIoT.060105
Received: January 15, 2022 Accepted: March 08, 2022

EEA_7	EEA_6
7.998 594	7.998 594
7.998 594	7.998 594
23.5	7.998 594
23.5	7.998 594
23.5	19.99 994
23.5	19.99 994
7.998 594	23.5
7.998 594	23.5
26.99 995	7.998 594
2.966 058	23.5
7.998 594	23.5
19.99 994	23.5
7.998 594	2.966 058
26.99 995	7.998 594
23.5	26.99 995
2.966 058	23.5
2.966 058	2.966 058
7.998 594	23.5
5.491 812	5.491 812
23.5	26.99 995
26.99 995	7.998 594
7.998 594	23.5
26.99 995	7.998 594
23.5	26.99 995
7.998 594	23.5
7.998 594	5.491 812

Table 9: The aggregated decision matrix.

EEA_7	EEA_6	EEA_5	EEA_4	EEA_3	EEA_2	EEA_1	
618	594	345	23.5	618	7.163	573	EES
573	594	952	23.5	705	23.5	33	EES
667	594	286	953	953	573	594	EES
286	594	286	594	286	33	594	EES
867	994	822	058	57	058	082	EES
331	994	618	994	331	018	904	EES
573	23.5	618	23.5	867	904	23.5	EES
594	23.5	665	594	573	573	286	EES
283	594	331	594	822	018	286	EES
57	23.5	2	904	573	705	57	EES
082	23.5	822	058	153	594	535	EES
663	23.5	286	23.5	822	57	23.5	EES
618	058	618	23.5	867	904	23.5	EES
617	594	286	904	573	57	286	EES
23.5	995	153	23.5	822	904	705	EES
57	23.5	2	594	573	705	57	EES
867	058	573	331	867	949	23.5	EES
573	23.5	283	23.5	262	331	33	EES
406	812	014	594	573	454	406	EES
23.5	995	488	23.5	822	976	705	EES
283	594	23.5	904	822	705	286	EES
573	23.5	573	23.5	262	454	573	EES
617	594	23.5	594	573	705	286	EES
23.5	995	406	23.5	014	812	454	EES
573	23.5	594	23.5	286	57	573	EES
573	454	822	014	7.163	014	014	EES

Table 10: The values of the WPM method.

EES
EES
EES
EES
EES
EES
EES
EES
EES
EES
EES
EES
EES
EES
EES
EES
EES
EES
EES
EES
EES
EES
EES
EES
EES
EES

DOI: https://doi.org/10.54216/JISIoT.060105
Received: January 15, 2022 Accepted: March 08, 2022

EEA_1	EEA_2	EEA_3	EEA_4	EEA_5	EEA_6	EEA_7
529	66	365	334	648	882	365
323	394	015	394	585	756	909
127	06	277	277	223	127	447
033	358	859	033	859	033	859
71	239	426	239	914	932	191
097	304	159	186	459	186	159
979	692	318	979	973	979	282
591	138	138	983	995	983	983
401	556	272	731	136	731	401
66	387	036	567	843	253	66
106	723	551	51	899	226	96
259	993	528	259	638	259	29
094	907	153	094	308	47	308
38	793	465	148	38	771	724
55	562	91	68	308	782	68
971	893	044	094	23	315	971
807	891	812	477	457	679	812
535	009	289	543	945	543	492
407	098	855	42	006	591	407
69	079	293	034	47	567	034
623	306	901	171	985	391	623
784	786	228	055	784	055	784
392	846	513	69	803	69	073
652	635	844	609	022	989	609
5	585	283	885	34	885	5
405	405	017	405	224	226	573

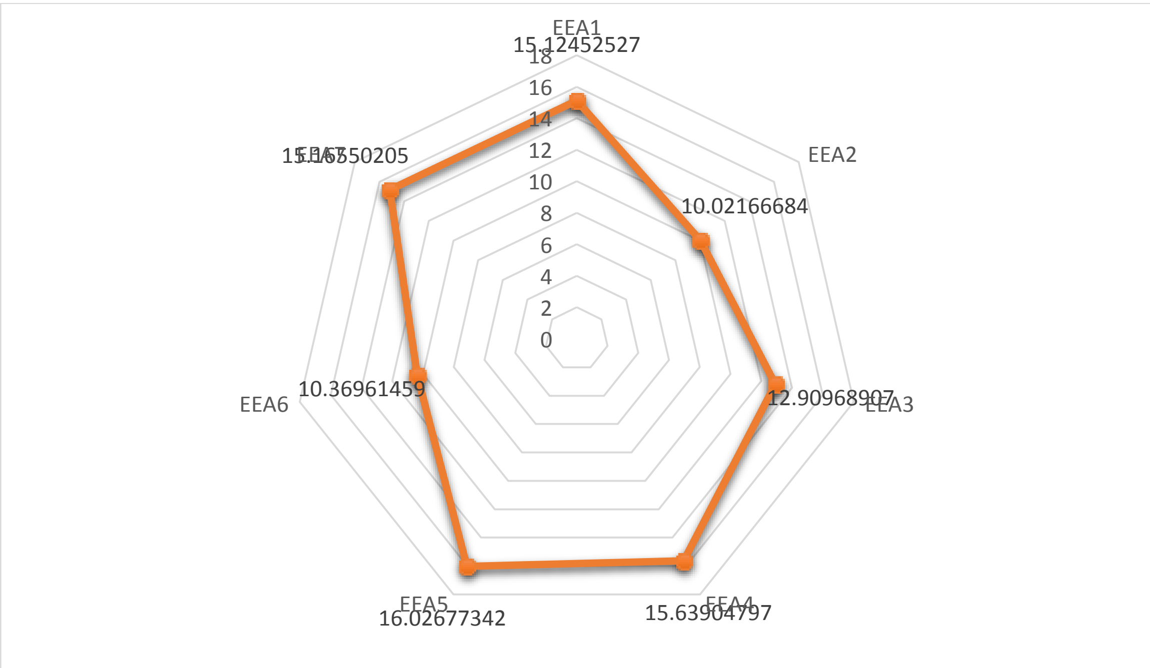

Figure 4: The rank of alternatives.

DOI: https://doi.org/10.54216/JISIoT.060105
Received: January 15, 2022 Accepted: March 08, 2022

6. Conclusion

Because of the country's rapid industrialization, urbanization, and rising population, its energy demands are only going to rise. There will be a rise in environmental concerns as a result of an increase in energy use. To address these problems, India needs to establish a varied energy policy that includes more renewable energy sources. We set out to use MCDM and Shannon's entropy to assess the most environmentally friendly energy sources.

Vietnam’s energy industry has been described in terms of its history, current state, and potential future directions in this report. Both renewable and nonrenewable energy sources have advantages and drawbacks that need to be considered. To evaluate both renewable and non-renewable energy sources, this research takes into account both sustainable and non-renewable power sources

The weights of the various criteria and sub-criteria are calculated using the spherical fuzzy AHP approach. Following environmental, technological, economic, cultural, and adaptable considerations were found to be of secondary importance. After that, MCDM approaches are utilized to rank and rate the options that have been studied. It was found that solar energy was the best option for Vietnam, followed by wind and hydropower. Based on research, the study created fourteen mixed energy scenarios that included the first five sustainable sources.

References

[1] B. Moldan, S. Janoušková, and T. Hák, “How to understand and measure environmental sustainability: Indicators and targets,” *Ecological Indicators*, vol. 17, pp. 4–13, 2012.

[2] B. Atilgan and A. Azapagic, “An integrated life cycle sustainability assessment of electricity generation in Turkey,” *Energy Policy*, vol. 93, pp. 168–186, 2016.

[3] R. K. Singh, H. R. Murty, S. K. Gupta, and A. K. Dikshit, “An overview of sustainability assessment methodologies,” *Ecological indicators*, vol. 9, no. 2, pp. 189–212, 2009.

[4] B. M. Eren, N. Taspinar, and K. K. Gokmenoglu, “The impact of financial development and economic growth on renewable energy consumption: Empirical analysis of India,” *Science of the Total Environment*, vol. 663, pp. 189–197, 2019.

[5] B. Dudley, “BP statistical review of world energy statistical review of world,” *bp. com*, 2019.

[6] S. K. Saraswat and A. K. Digalwar, “Evaluation of energy alternatives for sustainable development of energy sector in India: An integrated Shannon’s entropy fuzzy multi-criteria decision approach,” *Renewable Energy*, vol. 171, pp. 58–74, 2021.

[7] S. Ghosh, “Electricity supply, employment and real GDP in India: evidence from cointegration and Granger-causality tests,” *Energy Policy*, vol. 37, no. 8, pp. 2926–2929, 2009.

[8] L. Tripathi, A. K. Mishra, A. K. Dubey, C. B. Tripathi, and P. Baredar, “Renewable energy: An overview on its contribution in current energy scenario of India,” *Renewable and Sustainable Energy Reviews*, vol. 60, pp. 226–233, 2016.

[9] D. P. Sen Gupta and D. R. Ahuja, “Options for Adjusting Indian Standard Time for Saving Energy (Final Report Submitted to Bureau of Energy Efficiency, Govt. of India, Ministry of Power)(NIAS Report No. R3-2011),” 2011.

[10] S. Ali, “The Future of Indian Electricity Demand: How much, by whom, and under what conditions?,” 2018.

[11] A. Evans, V. Strezov, and T. J. Evans, “Assessment of sustainability indicators for renewable energy technologies,” *Renewable and sustainable energy reviews*, vol. 13, no. 5, pp. 1082–1088, 2009.

[12] L. Stamford and A. Azapagic, “Sustainability indicators for the assessment of nuclear power,” *Energy*, vol. 36, no. 10, pp. 6037–6057, 2011.

[13] N. Onat and H. Bayar, “The sustainability indicators of power production systems,” *Renewable and Sustainable Energy Reviews*, vol. 14, no. 9, pp. 3108–3115, 2010.

[14] B. C. Ervural, S. Zaim, O. F. Demirel, Z. Aydin, and D. Delen, “An ANP and fuzzy TOPSIS-based SWOT analysis for Turkey’s energy planning,” *Renewable and Sustainable Energy Reviews*, vol. 82, pp. 1538–1550, 2018.

[15] E. Santoyo-Castelazo and A. Azapagic, “Sustainability assessment of energy systems: integrating environmental, economic and social aspects,” *Journal of Cleaner Production*, vol. 80, pp. 119–138, 2014.

[16] S. J. W. Klein and S. Whalley, “Comparing the sustainability of US electricity options through multi-criteria decision analysis,” *Energy Policy*, vol. 79, pp. 127–149, 2015.

DOI: https://doi.org/10.54216/JISIoT.060105

Received: January 15, 2022 Accepted: March 08, 2022

[17] J. J. C. Barros, M. L. Coira, M. P. De la Cruz López, and A. del Caño Gochi, “Assessing the global sustainability of different electricity generation systems,” *Energy*, vol. 89, pp. 473–489, 2015.
[18] R. Srikanth, “India’s sustainable development goals–Glide path for India’s power sector,” *Energy Policy*, vol. 123, pp. 325–336, 2018.
[19] K. K. Pandey and H. Rastogi, "Effect of energy consumption & economic growth on environmental degradation in India: A time series modeling," *Energy Procedia*, vol. 158, pp. 4232–4237, 2019.
[20] C. Kahraman and İ. Kaya, “A fuzzy multicriteria methodology for selection among energy alternatives,” *Expert systems with applications*, vol. 37, no. 9, pp. 6270–6281, 2010.
[21] G. Büyüközkan and S. Güleryüz, “Evaluation of Renewable Energy Resources in Turkey using an integrated MCDM approach with linguistic interval fuzzy preference relations,” *Energy*, vol. 123, pp. 149–163, 2017.
[22] S. K. Jha and H. Puppala, “Prospects of renewable energy sources in India: Prioritization of alternative sources in terms of Energy Index,” *Energy*, vol. 127, pp. 116–127, 2017.
[23] J. J. D. Nesamalar, P. Venkatesh, and S. C. Raja, "The drive of renewable energy in Tamilnadu: Status, barriers, and future prospect," *Renewable and Sustainable Energy Reviews*, vol. 73, pp. 115–124, 2017.
[24] S. K. Kar, A. Sharma, and B. Roy, “Solar energy market developments in India,” *Renewable and sustainable energy reviews*, vol. 62, pp. 121–133, 2016.
[25] S. K. Sahoo, “Renewable and sustainable energy reviews solar photovoltaic energy progress in India: A review,” *Renewable and Sustainable Energy Reviews*, vol. 59, pp. 927–939, 2016.
[26] S. Ahmad and R. M. Tahar, “Selection of renewable energy sources for sustainable development of electricity generation system using analytic hierarchy process: A case of Malaysia,” *Renewable energy*, vol. 63, pp. 458–466, 2014.
[27] A. Sharma, J. Srivastava, S. K. Kar, and A. Kumar, “Wind energy status in India: A short review,” *Renewable and sustainable energy reviews*, vol. 16, no. 2, pp. 1157–1164, 2012.
[28] S. K. Saraswat, A. K. Digalwar, S. S. Yadav, and G. Kumar, "MCDM and GIS-based modeling technique for assessment of solar and wind farm locations in India," *Renewable Energy*, vol. 169, pp. 865–884, 2021.
[29] A. Jain, P. Das, S. Yamujala, R. Bhakar, and J. Mathur, “Resource potential and variability assessment of solar and wind energy in India,” *Energy*, vol. 211, p. 118993, 2020.
[30] S. Sen, S. Ganguly, A. Das, J. Sen, and S. Dey, “Renewable energy scenario in India: Opportunities and challenges,” *Journal of African Earth Sciences*, vol. 122, pp. 25–31, 2016.
[31] H.-C. Lee and C.-T. Chang, “Comparative analysis of MCDM methods for ranking renewable energy sources in Taiwan,” *Renewable and Sustainable Energy Reviews*, vol. 92, pp. 883–896, 2018.
[32] F. Kutlu Gündoğdu and C. Kahraman, “Spherical fuzzy analytic hierarchy process (AHP) and its application to industrial robot selection,” in *International Conference on Intelligent and Fuzzy Systems*, 2019, pp. 988–996.
[33] A. Görener, B. Ayvaz, A. O. Kuşakcı, and E. Altınok, “A hybrid type-2 fuzzy based supplier performance evaluation methodology: The Turkish Airlines technic case,” *Applied Soft Computing*, vol. 56, pp. 436–445, 2017.
[34] F. Kutlu Gündoğdu and C. Kahraman, “Spherical fuzzy sets and spherical fuzzy TOPSIS method,” *Journal of intelligent & fuzzy systems*, vol. 36, no. 1, pp. 337–352, 2019.
[35] M. K. Yilmaz, A. O. Kusakci, M. Aksoy, and U. Hacioglu, “The evaluation of operational efficiencies of Turkish airports: An integrated spherical fuzzy AHP/DEA approach,” *Applied Soft Computing*, p. 108620, 2022.

DOI: https://doi.org/10.54216/JISIoT.060105
Received: January 15, 2022 Accepted: March 08, 2022