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Windmill Global Sourcing in an Initiative Using a Spherical Fuzzy Multiple-Criteria Decision Prototype

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Abstract: The government of Karnataka has resolved to promote and employ an increasing number of alternative fuels, particularly, wind energy. Selecting a windmill supplier is a key decision when developing a wind energy project, and investors must evaluate various qualitative and quantitative variables that interact symmetrically to discover the best source. As a result, a multi-criteria decision-making procedure is applied to choose a wind turbine provider for wind power projects. A variety of approaches have been used to address this judgment process, some of which were predicated on the use of multi-criteria judgment techniques alone or in conjunction with some different multiple-criteria decision approaches. In this study, the researchers advocated selecting windmill producers for geothermal power generation using a judgment method based on a spherical fuzzy system. After the analyses of the last stage of this research, turbine manufacturers for installations could be suggested. The purpose of this research was to develop a fuzzy multi-criteria foundation for choosing appropriate rotor makers for electricity production. Specialists can utilize the conclusions of this study to choose an appropriate windmill operator in other states, including for green initiatives of a similar nature.

Keywords: supplier evaluation for wind turbines; fuzzy theory; multiple-criteria decision modeling; spherical fuzzy sets; sustainable sources

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1. Introduction

As per the Global Wind Energy Council, to avoid the greenhouse effect caused by a temperature increase of 2 °C over the pre-industrial level, humanity needs to put in place at least 180 GW of additional renewable power annually. Karnataka has the higher amount of renewable energy sources, including renewable power, compared to any province. Renewable power stations are constructed in Karnataka based on wind speed and rating [1]. The construction methods' features and their types, the rotational speed of the windmills, the role of the wings in the windmills, the raw material in use for blade construction, the number of blades used and why, the form of the wings, the troubles with wind generators and detectors positioned in a wind turbine are all important considerations in wind power generation. The act of harnessing and transforming environmental air currents toward useful electricity for everyday usage is known as electricity production. Windmills must be deployed and installed to fully utilize the wind energy. The windmills are placed on land. As a result, the wind turbine is an integral part of wind energy installations. Currently, there are many wind turbine manufacturers. The time it takes to complete a wind energy project and achieve its operational efficiency is heavily influenced by which supplier was chosen. A multi-criteria decision-making approach can be used to pick a wind turbine supplier for wind energy projects. When many criteria (or objectives) must be examined together to generate an overall score of the possibilities, multi-criteria decision-making approaches are an optimal way of making decisions [2]. A decision support system for wind energy projects using multi-criteria decision-making based on spherical fuzzy sets assists project managers in assessing and choosing the best options. In light of this, the wind turbine itself is a crucial part of wind energy installations. The market for wind turbines is now very competitive. The time it takes to complete a project and how well it operates are both greatly impacted by the choice of an appropriate provider. As a result, making this choice is difficult and involves taking many elements into account. A multi-criteria decision-making procedure can be used to choose a wind turbine supplier for wind power generation projects. Multi-criteria decision-making approaches can be defined as decision-making processes utilized when a number of criteria (or objectives) must be taken into account simultaneously in order to rank the available possibilities [2,3].

The Spherical Fuzzy Analytical Hierarchy Process technique was developed by Gundogdu and Kahraman [4]. It is a modification of the analytical hierarchy process which also employs spherical fuzzy sets. In this research, the spherical fuzzy analytical hierarchy process was used to evaluate the profitability of specific eligibility criteria.

The authors of this work suggest a multi-criteria decision-making model based on spherical fuzzy sets for choosing wind turbine suppliers for wind energy projects. In this study, the final evaluation and choice of a wind turbine provider are made using two multi-criteria decision-making techniques: the Weighted Aggregated Sum Product Assessment (WASPAS) and the Spherical Fuzzy Analytic Hierarchy Process (SF-AHP). In order to show how the suggested methodology might be applied, a final application is shown.

2. Literature Study

As the review of the literature that we conducted demonstrated, multi-criteria decision-making deviates little from operational research in that it deals with determining optimal solutions in complex scenarios involving many indices, competing aims, and different criteria. This extensively utilized strategy in the area of energy budgeting is gaining popularity since it gives decision-makers the freedom to make decisions while considering all aspects. Only a few studies have employed spherical fuzzy sets to address several requirements for geothermal power generation, aiding project managers in evaluating and selecting the best options. In this paper, we present fuzzy multi-criteria decision-making criteria for choosing a power station supplier. Judgment Analysis is a useful technique for addressing problems involving several players, criteria, and goals. The list of related previous studies is shown in Table 1.

Table 1. Literature Survey.

Researchers	Result Analysis
Hsing Chen Lee et al. [5]	To assess alternative energy sources, the author employed multi-criteria designs. The software used in this investigation was Weighted Sum Model, VlseKriterijumska Optimizacija I Kompromisno Resenje, Technique for Order of Preference by Similarity Ideal Solution, and Elimination and Choice Translating Reality.
Abhisek Kumar et al. [3]	The study’s is helpful for electricity judgment and will act as a guideline for Taiwan’s electric plan. Many multi-criteria decision-making solutions for renewable energy are discussed.

Table 1. *Cont.*

Researchers	Result Analysis
Muratolak et al. [6]	To select green power possibilities, the authors used an Analytical Hierarchy Process with intervals of intuitionistic fuzzy sets and a persistent Fuzzy Technique for Order of Preference by Similarity Ideal Solution techniques in the research.
Arash Sadeghi et al. [7]	A fuzzy multi-criteria decision-making model was used to assess four alternative renewable energy sources: renewable radiation, hydroelectricity, renewable power, and fuel cells. To assess the four broad categories in this study, the author used the Fuzzy Analytical Hierarchy Process and Fuzzy Technique for Order of Preference by Similarity Ideal Solution.
Tien-Chin Wang et al. [8]	To choose a solar array supplier for an electricity venture in Taiwan, the author used a Fuzzy Multi-Criteria paradigm that included the Fuzzy Analytical Hierarchy Process with Data Envelopment Analysis (DEA). A fuzzy-based multi-criteria decision-making strategy for making a selection in hazy and unexpected events was developed in this work.
Sarmad Ishfaq et al. [9]	Analytical Hierarchy Process, Technique for Order of Preference by Similarity Ideal Solution, and VlseKriterijumska Optimizacija I Kompromisno Resenje are the three major multi-criteria decision-making models discussed in this study. To find the greatest sources of energy for Pakistan, researchers used the three methodologies.
Gülçin Büyüközkan et al. [10]	To properly analyze a renewable energy sources strategy dilemma, the author used hesitant fuzzy linguistic term sets.
S. K. Saraswat et al. [11]	For the evaluation of wind and solar power farm locations in India, the authors used Geographical Information System and Multi-Criteria techniques. Their findings can be utilized to expand renewable energy policies and assess the feasibility of projects that have already been planned.
Yunna Wu et al. [12]	The author devised a Fuzzy Multi-Criteria decision-making concept according to a weighted perspective in order to assess the feasibility of solar and wind power systems. This research provides useful findings for choosing the most appropriate green power generation system given uncertain criteria, by offering publicly uncertain investors many possibilities.
Mohsen Ramezanzade et al. [13]	The author presented a Multi-Criteria Fuzzy Hybrid version for ranking renewable energy projects in a fuzzy scenario that combined VlseKriterijumska Optimizacija I Kompromisno Resenje, vicinity from a weighted average method, and continuous-ratio assessment methods.
Lee et al. [14]	When designing a power station, the authors used a multi-criteria approach that bleneds interpretive structural modelling with a fuzzy analytic network process to identify ideal windmills. The best-suited rotor for building could be identified just after the simulations. The insights from this study can aid judgment in selecting the most appropriate wind generators.
Nansheng Pang et al. [15]	The authors used fuzzy preference programming and an analytic network technique to develop a framework for windfarm unit determination. The findings revealed that the Goldwind's 2.5 W unit will provide the best assessment value, which is in line with the growing share of the market of permanent-magnet synchronous direct-drive wind turbines.
Meng Shao et al. [16]	The authors reviewed multi-criteria decision-making applications for renewable power site selection. In the five stages of the site selection, the authors distinguished between two types of criteria and approaches. According to the statistics, the most often used technologies in this sector are hybridized geographical information systems and multi-criteria decision-making.
Francisco G. Montoya et al. [17]	The authors demonstrated that multi-objective evolutionary computation can be applied to windmill decision challenges.
Shankar Chakraborty [18]	In this study, five real-time production-related difficulties were considered while selecting (a) flexible manufacturing systems, (b) machines in flexible manufacturing cells, (c) automated guided vehicles, (d) automated inspection systems, and (e) industrial robots. It was noted that the Weighted Aggregated Sum Product Assessment approach yielded largely respectable outcomes for each of these five difficulties.

Table 1. *Cont.*

Researchers	Result Analysis
Badalpur Mohammadreza et al. [19]	In this study, the authors identified and assessed the risks associated with a road construction project in Iran. The findings revealed that the most significant risks among those identified were the inaccessibility or inappropriateness of barrow pits, the loss of key personnel during the project's life cycle, and the use of inexperienced subcontractors. Additionally, among multi-criteria decision-making methodologies, this paper recommended the Weighted Aggregated Sum Product Assessment method as an appropriate method that would provide a higher level of accuracy for risk assessment in a practical setting

3. Methods

3.1. Making Decisions Based on Multiple Critera

In operations research, the subfield of multi-criteria decision-making examines how to make choices when several, potentially contradictory factors must be taken into account (both in daily life and in settings such as business, government, and medicine). Multi-criteria decision-making approaches are crucial tools that help decision-makers in discrete scenarios make choices. Multi-criteria decision and planning problems must be organized and resolved using multi-criteria decision making. Decision-makers who face comparable problems are intended to receive assistance. Decision-makers' preferences must be used to differentiate between alternatives because there is typically more than one best solution to such problems. Here, we used the multi-criteria decision-making approaches of Weighted Aggregated Sum Product Assessment and Spherical Fuzzy Analytic Hierarchy Process, which address these issues on the basis of preferences.

3.2. Graph for the Research

The fuzzy multi-criteria decision making technique offers an outstanding strategic procurement prototype via distinct phases as schematically demonstrated in Figure 1.

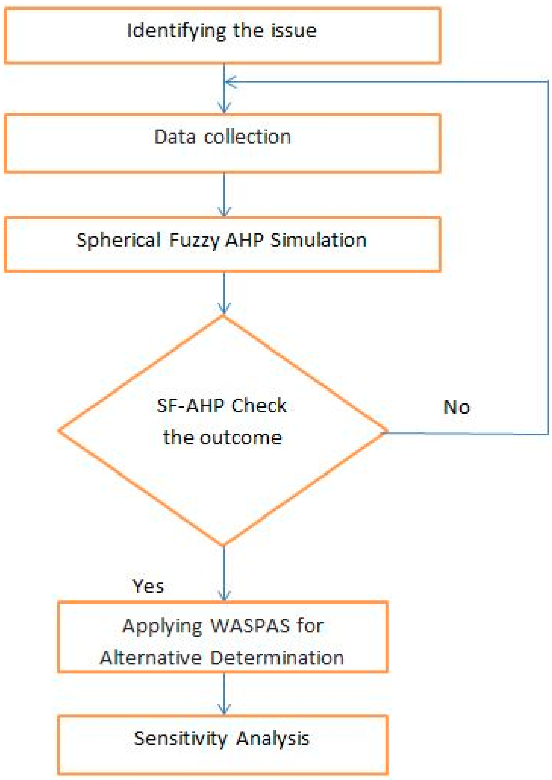

Figure 1. Research Graph.

Step 1: Identifying the issue

To begin, professionals and researchers outline the sets of factors that influence the wind turbine supplier selection.

Step 2: Use of the Spherical Fuzzy Analytical Hierarchy Process

The Spherical Fuzzy Analytical Hierarchy Process model takes into account clear target weighting factors for the following evaluation stage.

Step 3: Alternative Determination using the Weighted Aggregated Sum Product Assessment

The Weighted Aggregated Sum Product Assessment approach combines the Weighted Sum model and the Weighted Product model. As a result, the Weighted Aggregated Sum Product Assessment methodology is used to rate all of the turbine vendors identified at this step.

3.3. Spherical Fuzzy Sets Concept

Gundogdu et al. developed the spherical fuzzy sets theory by combining Pythagorean fuzzy sets [1] and Neutrosophic sets [20]. The concept is founded on the idea that judgments may be expressed in terms of associated and unrelated dimensions, so a judgment can apply the subsequent enlargement of fuzzy sets by employing a spherical model [4].

The U_1 spherical fuzzy sets $\widetilde{A}_s$ universe is stated in the following way:

$$\widetilde{A}_s = \left\{ x,\ \mu_{\widetilde{A}_s}(x),\ v_{\widetilde{A}_s}(x),\ \pi_{\widetilde{A}_s}(x) \middle| \ x \in U_1 \right\} \tag{1}$$

where:

$$\mu_{\widetilde{A}_s}(x) : U_1 \to [0,1], v_{\widetilde{A}_s}(x) : U_1 \to [0,1], \text{ and } \pi_{\widetilde{A}_s}(x) : U_1 \to [0,1]$$

and

$$0 \le \mu^2_{\widetilde{A}_s}(x) + v^2_{\widetilde{A}_s}(x) + \pi^2_{\widetilde{A}_s}(x) \le 1 \text{ with } \forall\, x\ \in U_1 \tag{2}$$

The degree of membership is $\mu_{\widetilde{A}_s}(x)$, the degree of non-membership is $v_{\widetilde{A}_s}(x)$, and the hesitancy of x to $\widetilde{A}_s$ is $\pi_{\widetilde{A}_s}(x)$.

Gundogdu and Kahraman [4] described and demonstrated standard spherical fuzzy set arithmetic procedures in this way.

3.4. Spherical Fuzzy Analytical Hierarchy Process Procedure

Gundogdu and Kahraman [4] created a five-stage spherical fuzzy analytical hierarchy process strategy:

Stage 1: Make a conceptual model with a hierarchical system

The result is a three-tiered structural framework. Depending on a score index, the model aims to obtain Level 1. The scoring index is calculated at tier two of the structure using a list of n criteria. The third stage designates a set of m possibilities for A, whereby m is less than two.

Stage 2: Make suitable primary data gathering matrices for the criteria using fuzzified options based on Gundogdu and Kahraman's [4] language principles, as shown in Table 2. Equations (3) and (4) are used to generate the index of the score (SI) for each choice.

Table 2. Important lexicons in linguistics.

	(μ,v,π)	List of Scores
Significantly more significant (SMS)	(0.9, 0.1, 0.0)	9
Extremely significant (ES)	(0.8, 0.2, 0.1)	7
Extremely vital (EV)	(0.7, 0.3, 0.2)	5
Little more significant (LMS)	(0.6, 0.4, 0.3)	3
Likewise crucial (LC)	(0.5, 0.4, 0.4)	1
Minimal relevancy (MR)	(0.4, 0.6, 0.3)	1/3
Modest precedence (MP)	(0.3, 0.7, 0.2)	1/5
Extremely minor significance (EMS)	(0.2, 0.8, 0.1)	1/7
Extremely minor importance (EMI)	(0.1, 0.9, 0.0)	1/9

$$\mathrm{SI} = \sqrt{|100 * [(\mu_{\widetilde{A}_S} - \pi_{\widetilde{A}_S})^2 - (\mathrm{v}_{\widetilde{A}_S} - \pi_{\widetilde{A}_S})^2]|} \tag{3}$$

These are all the choices with significantly more significant, extremely significant, extremely vital, little more significant, and likewise crucial.

$$\frac{1}{\mathrm{SI}} = \frac{1}{\sqrt{|100 * [(\mu_{\widetilde{A}_S} - \pi_{\widetilde{A}_S})^2 - (v_{\widetilde{A}_S} - \pi_{\widetilde{A}_S})^2]|}} \tag{4}$$

Minimal relevancy, modest precedence, extremely minor significance, and extremely minor importance are examples of these alternatives.

Stage 3: Check for consistency in each pairwise comparison matrix. The scoring values that correspond to the linguistic terms in the pairwise comparisons are translated. Then, using a 10% consistency ratio threshold, we determine the standard comparison matrix:

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \tag{5}$$

The following is how to calculate the Consistency Index (CI):

$$\mathrm{CI} = \frac{\lambda_{max} - n}{n - 1} \tag{6}$$

where λ_{max} denotes the highest prioritization of the matrices, and n specifies the range of needs.

Different variables affect the Random Index (RI) [21].

Stage 4: Compute the spherical fuzzy weights of the criteria and alternative solutions. To determine the grading of every selection in regard to every criterion, The significance is reveal as:

$$\begin{aligned} \mathrm{SWM}_w(A_{S1}, \ldots, A_{Sn}) &= w_1 A_{S1} + \ldots + w_n A_{Sn} \\ &= \langle \left[1 - \prod_{i=1}^{n} (1 - \mu^2{}_{A_{Si}})^{w_i}\right]^{1/2}, \prod_{i=1}^{n} v^{w_i}{}_{A_{Si}}, \left[\prod_{i=1}^{n} (1 - \mu^2{}_{A_{Si}})^{w_i} - \prod_{i=1}^{n} (1 - \mu^2{}_{A_{Si}} - \pi^2{}_{A_{Si}})^{w_i}\right]^{1/2} \rangle \end{aligned} \tag{7}$$

where $w = \frac{1}{n}$.

Stage 5: Evaluate the current value depending on the stage succession in increasing order. By modifying the spherical quantities at each stage of the escalating architecture, the final score of the variants can be predicted. During this stage, the calculation can be carried out in one of two ways. The first way is to use the weighting factor in Equation (8) to de-fuzzify the criteria values:

$$\left(\widetilde{w}_j^S\right) = \sqrt{\left|100 * \left[\left(3\mu_{\widetilde{A}_S} - \frac{\pi_{\approx A_S}}{2}\right)^2 - \left(\frac{\mathrm{v}_{\approx A_S}}{2} - \pi_{\widetilde{A}_S}\right)^2\right]\right|} \tag{8}$$

Equation (9) is then used to normalize the criteria weights, and Equation (10) is used to perform a spherical fuzzy multiplication:

$$\overline{w}_j^S = \frac{S\left(\widetilde{w}_j^S\right)}{\sum_{j=1}^n S\left(\widetilde{w}_j^S\right)} \tag{9}$$

$$A_{S_{ij}} = \overline{w}_j^S * A_{S_i} = \langle \left(1 - \left(1 - \mu^2{}_{\widetilde{A}_S}\right)^{\overline{w}_j^S}\right)^{1/2}, v^{\overline{w}_j^S}{}_{\widetilde{A}_S}, \left(\left(1 - \mu^2{}_{\widetilde{A}_S}\right)^{\overline{w}_j^S} - \left(1 - \mu^2{}_{\widetilde{A}_S} - \pi^2{}_{\widetilde{A}_S}\right)^{\overline{w}_j^S}\right)^{1/2} \rangle \tag{10}$$

with $\forall i$.

The performance as a graduate value $\left(\widetilde{\mathrm{F}}\right)$ for every selection A_i is calculated using Equation (11).

$$\widetilde{\mathrm{F}} = \sum_{j=1}^n \widetilde{A}_{S_{ij}} = \widetilde{A}_{S_{i1}} + \widetilde{A}_{S_{i2}} + \ldots + \widetilde{A}_{S_{in}} \tag{11}$$

Another option is to resume computing while the criteria weights are de-fuzzing. The following is how the globe spherical fuzzy weights are calculated:

$$\prod_{j=1}^n \widetilde{A}_{S_{ij}} = \widetilde{A}_{S_{i1}} * \widetilde{A}_{S_{i2}} * \ldots * \widetilde{A}_{S_{in}} \tag{12}$$

Equation (11) is then used to obtain the definitive gain and extension of each alternative.

3.5. Methodology of Weighted Aggregated Sum Product Assessment (WASPAS)

The Weighted Sum Model method is straightforward to use, comprehend, and implement. It calculates the overall score of an alternative as the weighted combination of the feature values. This is perhaps the most widely used method. The Weighted Product Model is intended to prevent low-attribute-value options from being selected. It determines the score for each option by combining the normalized evaluation of each character's capabilities with the prominence of that aspect.

The Weighted Aggregated Sum Product Assessment method's processing methodology can be summed up as follows:

Stage 1: Normalization is applied to the selection matrix

Whether or not the criteria are favorable determines the procedure for normalizing the decision model for the Weighted Aggregated Sum Product Assessment approach. Equation (13) shows how to normalize the decision matrix for the advantageous choice criterion:

$$q_{ij} = \frac{x_{ij}}{\max x_{ij}}, \ i = 1,2,\ldots,n; \ j = 1,2,\ldots,m \tag{13}$$

As illustrated in Equation (14), for non-beneficial eligibility criteria:

$$q_{ij} = \frac{\min x_{ij}}{x_{ij}}, \ i = 1,2,\ldots,n; \ j = 1,2,\ldots,m \tag{14}$$

Stage 2: By using the Weighted Sum Model technique, define the current relevance of the ith choice:

$$S_i^1 = \sum_{j=1}^n q_{ij} \times w_j \tag{15}$$

Stage 3: As indicated in Equation (16), the Weighted Product Model assesses the ith alternative's performance index:

$$S_i^2 = \prod_{j=1}^n \left(q_{ij}\right)^{w_j} \tag{16}$$

Stage 4: To obtain the overall relative importance, we use Equations (15) and (16) to create the Weighted Aggregated Sum Product Assessment technique. The following is the weighting summation, or, to be more exact, the generic criterion for weighed synthesizing of modular arithmetic operations:

$$F = \lambda S_i^1 + (1-\lambda) S_i^2 = \lambda \sum_{j=1}^{n} q_{ij} \times w_j + (1-\lambda) \prod_{j=1}^{n} (q_{ij})^{w_j} \quad (17)$$

where λ is the range of the coefficient value, and λ ∈ [0, 1] is the array. If no alternative is available for the quantity, λ is set to 0.5. An evaluation metric is used to rank the choices, with the preferred option obtaining the highest weight.

4. Results and Discussion

Several elements make the Indian market attractive to wind power investors. Apart from its environmental assets, the present administration is a great supporter of wind energy and subsidizing wind power projects to decrease investment risk and economic participation to experiment with and create new businesses. For the purpose of choosing the supplier of wind turbines in wind energy projects, the authors of this study developed a multi-criteria decision-making approach based on spherical fuzzy sets.

4.1. Criteria Used for the Supplier Selection

As indicated in Table 3 and Figure 2, all criteria were applied to evaluate wind turbine providers and the literature review.

Table 3. Criteria used for the supplier selection.

Criteria	Sub-Criteria	Researchers
The aspect of the Mechanism	Windmill operating and quality factor (AM1)	Amy H. I. Lee et al. [14], A. Ayca Supciller et al. [22] Abdel-Monem et al. [23]
	Eligible for upkeep (AM2)	
	Flow rate and velocity (AM3)	A. Ayca Supciller et al. [22] Abdel-Monem et al. [23]
Ecological	Utilization of the Area (EL1)	Data Amy H. I. Lee et al. [14] A. Ayca Supciller et al. [22] Abdel-Monem et al. [23]
	Effects on the Environment (EL2)	Abdel-Monem et al. [23]
	Fuss/pollution of the air (EL3)	A. Ayca Supciller et al. [22] Abdel-Monem et al. [23]
Technical	Allocation Timeframe (T1)	
	System Implementation Capability (T2)	Amy H. I. Lee et al. [14]
Ecological	Price of the venture (EC1)	Amy H. I. Lee et al. [14], Nansheng Pang et al. [15], A. Ayca Supciller et al. [22]
	Operational cost and upkeep (EC2)	Amy H. I. Lee et al. [14], A. Ayca Supciller et al. [22] Abdel-Monem et al. [23]
	Surplus (EC3)	A. Ayca Supciller et al. [22]

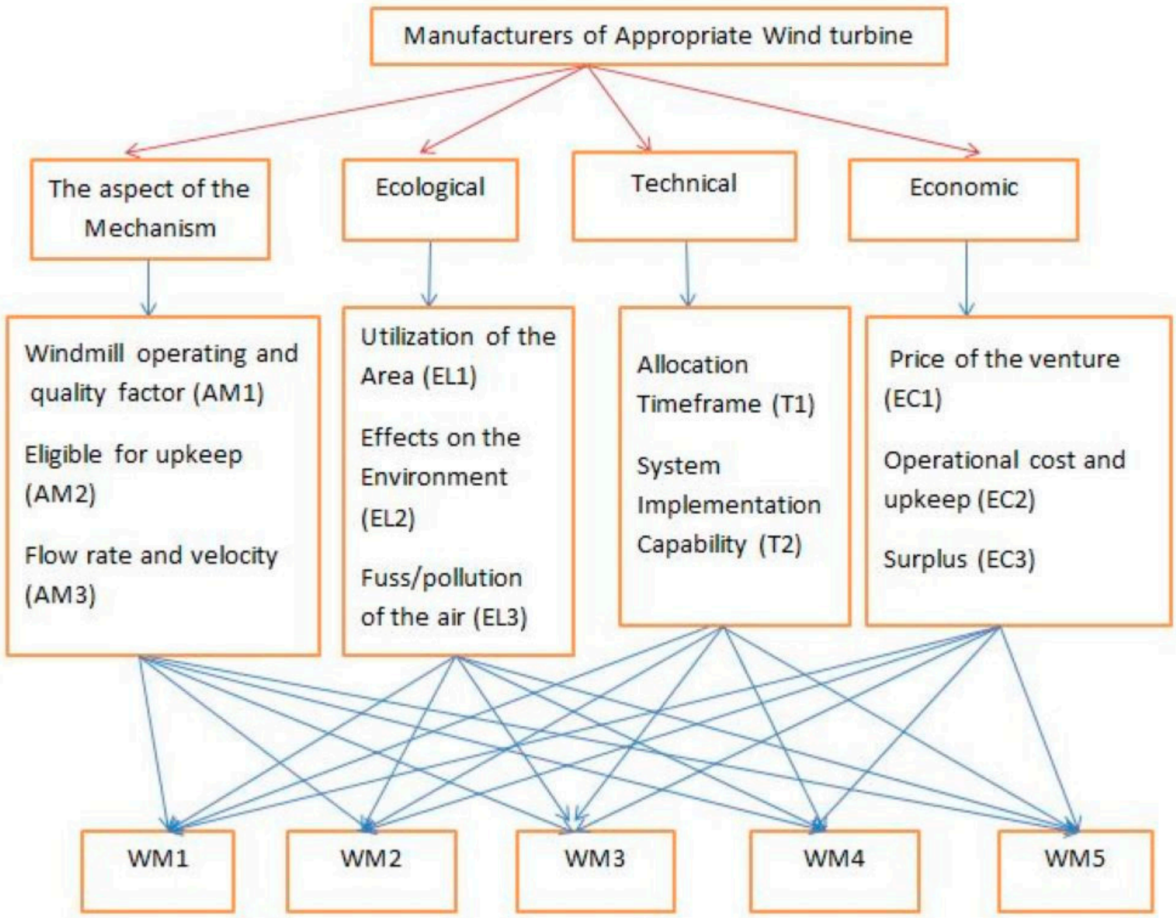

Figure 2. Criteria hierarchies, sub-criteria, and generator sources.

4.2. Findings Obtained Using the Spherical Fuzzy Analytic Hierarchy Process Model

The Spherical Fuzzy Analytic Hierarchy Process was used to establish the scores of all criteria in the study's second phase. Table 4 summarizes the findings of the Spherical Fuzzy Analytic Hierarchy Process model.

Table 4. Findings of the Spherical Fuzzy Analytic Hierarchy Process model.

Criterion		SF Scales		Crisp Weights
AM1	0.7893	0.2075	0.1898	0.0317
AM2	0.8695	0.1287	0.1020	0.0402
AM3	0.7181	0.2875	0.5707	0.0204
EL1	0.6410	0.3654	0.2507	0.0199
EL2	0.4505	0.4810	0.3667	0.0083
EL3	0.4546	0.4810	0.3648	0.0085
T1	0.4183	0.5258	0.3438	0.0072
T2	0.4230	0.5195	0.3461	0.0073
EC1	0.4300	0.5123	0.3511	0.0076
EC2	0.4300	0.5123	0.3511	0.0076
EC3	0.4166	0.5315	0.3433	0.0071

4.3. Criterion Values Matrices and Exponentially Weighted Matrices

The approximate amount criteria for assessing a windmill in the Weighted Aggregated Sum Product Assessment simulation were then utilized to de-fuzz the spherical fuzzy loads into script weightiness in the next step. Tables 5 and 6 illustrate the criterion values matrices and exponentially weighted matrices, respectively.

Table 5. Weighted Aggregated Sum Product Assessment judgement matrix, weighed and normalized for summary parts.

	WM1	**WM2**	**WM3**	**WM4**	**WWM5**
AM1	0.0317	0.0247	0.0176	0.0247	0.0176
AM2	0.0223	0.0313	0.0313	0.0134	0.0402
AM3	0.0113	0.0204	0.0113	0.0159	0.0159
EL1	0.0155	0.0199	0.0111	0.0155	0.0111
EL2	0.0036	0.0050	0.0028	0.0050	0.0083
EL3	0.0061	0.0085	0.0061	0.0085	0.0061
T1	0.0024	0.0043	0.0072	0.0043	0.0031
T2	0.0073	0.0057	0.0073	0.0041	0.0073
EC1	0.0076	0.0059	0.0042	0.0025	0.0025
EC2	0.0046	0.0076	0.0033	0.0046	0.0025
EC3	0.0055	0.0071	0.0039	0.0024	0.0071

Table 6. Weighted Aggregated Sum Product Assessment judgment matrix for multiplier parts, weighed and normalized.

	WM1	**WM2**	**WM3**	**WM4**	**WM5**
AM1	1.0000	0.9921	0.9815	0.9921	0.9815
AM2	0.9766	0.9899	0.9899	0.9568	1.0000
AM3	0.9881	1.0000	0.9881	0.9949	0.9949
EL1	0.9950	1.0000	0.9884	0.9950	0.9884
EL2	0.9930	0.9958	0.9909	0.9958	1.0000
EL3	0.9971	1.0000	0.9971	1.0000	0.9971
T1	0.9921	0.9963	1.0000	0.9963	0.9939
T2	1.0000	0.9982	1.0000	0.9957	1.0000
EC1	1.0000	0.9981	0.9955	0.9917	0.9917
EC2	0.9961	1.0000	0.9936	0.9961	0.9917
EC3	0.9982	1.0000	0.9958	0.9922	1.0000

For creating a judgment basis for selecting windmill operators, the study's authors recommend combining the Spherical Fuzzy Analytic Hierarchy Process and Weighted Aggregated Sum Product Assessment concepts. In the first step, the Spherical Fuzzy Analytic Hierarchy Process was used to calculate the significance of all criteria, and in the subsequent step, the Weighted Aggregated Sum Product Assessment methodology was utilized to rank all available suppliers.

4.4. Final Value from the Weighted Aggregated Sum Product Assessment

The aggregated utility function value Q_i was calculated to use the Q_{i1} (Weighted Sum Model) and (Weighted Product Model) Q_{i2} as indicated in Table 7. WM2, WM5, and WT1 were the top three windmill suppliers, with scores of 0.5555, 0.5312, and 0.5279, respectively. As a result, the supplier WM2 appeared to be the best option.

Table 7. Final value from the Weighted Aggregated Sum Product Assessment.

Options	$\mathbf{Q_{i_1}}$	$\mathbf{Q_{i_2}}$	$\mathbf{Q_i}$
WM1	0.1179	0.9379	0.5279
WM2	0.1403	0.9707	0.5555
WM3	0.1060	0.9236	0.5148
WM4	0.1007	0.9098	0.5053
WM5	0.1217	0.9407	0.5312

4.5. Ranking Various λ Attributes

Table 8 indicates the relative computational results depending on the correlation coefficients for the various parameters. It is worth mentioning that the value of a quantity does not lead to a change in the alternative's ranking. This study led to the development of a mixture multi-criteria decision-making model that works well for determining the supply chain and selection method in renewable energy projects, employing the Spherical Fuzzy Analytic Hierarchy Process and Weighted Aggregated Sum Product Assessment.

Table 8. Ranking of various λ attributes.

λ	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
WM1	0.8559	0.7739	0.6919	0.6099	0.5279	0.4459	0.3639	0.2819	0.1999	0.1179
WM2	0.8877	0.8046	0.7216	0.6385	0.5555	0.4725	0.3894	0.3064	0.2234	0.1403
WM3	0.8418	0.7601	0.6783	0.5966	0.5148	0.4331	0.3513	0.2695	0.1878	0.1060
WM4	0.8289	0.7480	0.6671	0.5862	0.5053	0.4244	0.3434	0.2625	0.1816	0.1007
WM5	0.8588	0.7769	0.6950	0.6131	0.5312	0.4493	0.3674	0.2855	0.2036	0.1217

5. Sensitivity Analysis

For the purposes of this article, the value of λ was 0.5 (λ = 0.5). The reliability and applicability of the suggested technique are then shown through a sensitivity analysis. The results of the suggested methodology's sensitivity analysis are described by altering the coefficient (λ) value's range from 0 to 1, which could affect the outcomes, as anticipated. It demonstrated the dependability and thoroughness of the fuzzy decision-making method for assessing wind turbine suppliers.

According to the sensitivity analysis of the Weighted Aggregated Sum Product Assessment model, Figure 3 shows the final evaluation scores and the final ranking of alternatives. In accordance to Equation (17), it was proved that the degree of precision λ in the range of 0.1, 0.2, 0.3, . . . , 1 can be employed to determine the coefficients. As a result, the coefficient was changed in the first portion of the sensitivity analysis. When the coefficient value (λ) was changed from 0 to 1, the results demonstrated that the optimal option remained the same. We could draw the conclusion that WM2 was always the best replacement. Additionally, WM5 and WM1 ranked second and third, appearing as superior alternatives among the candidates. It can be concluded that the recommended model is applicable to issues found in the real world. The reliability of the proposed fuzzy decision-making approach was investigated using a sensitivity analysis. In order to facilitate the assessment and choice of wind turbine vendors, the study successfully used a multi-criteria decision-making model that included the Spherical Fuzzy Analytic Hierarchy Process and the Weighted Aggregated Sum Product Assessment.

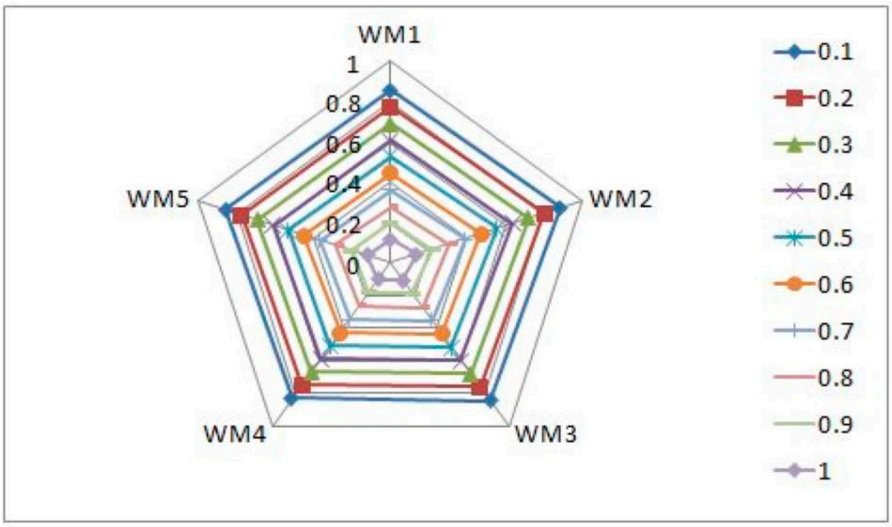

Figure 3. Sensitivity analysis of windmill suppliers for varying λ values.

6. Conclusions

This study designed a new multi-criteria decision-making framework for spherical fuzzy collections mill supply chains in wind energy applications. The described fuzzy multi-criteria decision-making technique to rate windmill producers for wind power generation uses the Spherical Fuzzy Analytic Hierarchy Process and the Weighted Aggregated Sum Product Assessment methods. The criterion values were adjusted using the Spherical Fuzzy Analytic Hierarchy Process. The Weighted Aggregated Sum Product Assessment ranked the turbine vendors based on the values obtained. A set of criteria for evaluating the turbine vendors was developed based on expert opinions, the literature, and the machine's attributes, as well as on environmental, technological, and financial concerns. The supplier WM2 appeared to be the most suitable, according to the data. This study used a combination of the Spherical Fuzzy Analytic Hierarchy Process and the Weighted Aggregated Sum Product Assessment to create a method for evaluating providers in the renewable energy sector. The results of the present study can be used as a benchmark in assessing providers of turbines not just for energy development, but also for other types of turbines. In the future, the study could be broadened to include multi-criteria decision-making methodologies such as the Technique for Order of Preference by Similarity Ideal Solution, the Data Envelopment Analysis, the Combined Compromise Solution, and others.

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