



Evaluating the Onshore Wind Farms Based on Multi-Criteria Decision-Making Model under Neutrosophic Set

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ABSTRACT

This work comprehensively evaluates onshore wind farms, focusing on their technological efficiency, environmental impact, economic viability, and societal implications. Onshore wind energy has emerged as a prominent renewable energy source, leveraging the kinetic power of wind to generate electricity on a substantial scale. The evaluation encompasses a detailed analysis of wind resource assessment, turbine technology, grid integration, environmental considerations, economic feasibility, and stakeholder engagement. Findings reveal that onshore wind farms exhibit commendable technological advancements, with modern turbines showcasing higher efficiency and capacity. Environmental assessments highlight their lower carbon footprint compared with conventional energy sources, albeit with considerations for land use and wildlife impacts. Economic evaluations emphasize the decreasing costs of wind energy, yet challenges persist concerning upfront investment and intermittency. Stakeholder engagement emerges as a crucial aspect, stressing the importance of community acceptance and regulatory compliance. The assessment illuminates the multifaceted aspects of onshore wind farms, underscoring their potential as a sustainable energy source while acknowledging the need to address technological, economic, and social barriers to widespread adoption. We use a multi-criteria decision-making (MCDM) model to evaluate onshore wind farms. The Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH) method is used to rank the alternatives. The MCDM method is applied under a single-valued neutrosophic set (SVNS), which addresses uncertainty in the evaluation process.

Keywords: MCDM ▪ Onshore Wind Farms ▪ Decision Making ▪ Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH) ▪ Single-Valued Neutrosophic Set

1. INTRODUCTION

Onshore wind energy is a cornerstone in the global pursuit of sustainable and renewable energy sources. In the quest to decarbonize power generation and mitigate climate-change impacts, onshore wind farms have emerged as pivotal contributors, harnessing the natural kinetic energy of wind to produce clean electricity on a significant scale [1, 2, 3].

The proliferation of onshore wind farms reflects the convergence of technological advancements, favorable geographical

conditions, and a growing recognition of the urgency to transition toward low-carbon energy sources. These sprawling landscapes adorned with towering turbines symbolize the promise of abundant and environmentally friendly energy generation [4, 5, 6, 7].

The significance of evaluating onshore wind farms transcends mere technological prowess; it extends to multifaceted dimensions spanning environmental impact, economic viability, technological innovation, and societal acceptance. At the core of this evaluation lies a nuanced understanding of the

opportunities, challenges, and potential trade-offs inherent in harnessing wind power for electricity generation [8, 9, 10].

Onshore wind farms are characterized by their ability to leverage strong and consistent wind resources, making them attractive propositions for renewable energy deployment. However, evaluating their efficacy necessitates an assessment of various factors, including wind resource assessment, turbine efficiency, grid integration, environmental implications, land-use considerations, and community engagement [11, 12].

The evolution of onshore wind technology is marked by innovations in turbine design, rotor efficiency, and enhanced grid connectivity, driving higher capacity factors and cost competitiveness. These advancements have propelled onshore wind farms into prominence within the renewable energy landscape, competing favorably with traditional fossil-fuel-based power generation [13, 14].

When many experts are present and a limited number of choices are available, one popular cognitive method for selecting the closest option or options is the decision-making process. However, given the intensive nature of the subject, finding an effective solution is not always simple. Uncertainties are among the most important elements when making a choice. To address these issues, academics have developed a variety of models in different contexts, such as fuzzy sets (FS), Atanassov intuitionistic fuzzy sets (A-IFS), and SVN [15, 16].

The uncertainties in the data may be effectively measured using these ideas. Numerous scientists and academics have investigated approaches within the multi-attribute group decision-making (MAGDM) framework that can accurately characterize fuzziness in the information used for decision-making. For example, Xu introduced mathematical operations for pairs of A-IFS, while Yager investigated the concept of intuitionistic fuzzy numbers. Xu et al. introduced an A-IFS clustering technique, and Zhang and Yu explained measurements between pairs of fuzzy and interval-valued fuzzy sets [17, 18].

In FS and A-IFS theories, an expert provides ratings with the condition that each degree is dependent on the others. Conversely, a decision-maker may provide evaluations impartially in various circumstances [19]. To address this issue, Smarandache combined three separate degrees to establish a neutrosophic set in 1998. Owing to the distinct attributes of each membership level [20], neutrosophic sets are important in information fusion when merging data from different sources [21, 22].

2. PRELIMINARIES

This section introduces the mathematical foundations of SVN.

Definition 1. A neutrosophic set can be given by

$$N = \{(x, \delta(x), X(x), \nu(x)) \mid x \in \Phi\},$$

where

$$\delta, X, \nu : \Phi \rightarrow]^{-}0, 1^{+}[,$$

and

$$^{-}0 \leq \sup \delta(x) + \sup X(x) + \sup \nu(x) \leq 3^{+}.$$

Definition 2. An SVN is represented as

$$N = \{(x, \delta(x), X(x), \nu(x)) \mid x \in \Phi\},$$

subject to

$$0 \leq \delta + X + \nu \leq 3.$$

Definition 3. Let two neutrosophic numbers be $N_1 = (\delta_1, X_1, \nu_1)$ and $N_2 = (\delta_2, X_2, \nu_2)$. Their complement is

$$N^c = (\nu, X, \delta).$$

The comparison, equality, intersection, and union operations are

$$N_1 \leq N_2 \quad \text{if} \quad \delta_1 \leq \delta_2, X_1 \geq X_2, \nu_1 \geq \nu_2,$$

$$N_1 = N_2 \quad \text{if} \quad N_1 \leq N_2 \text{ and } N_2 \leq N_1,$$

$$N_1 \cap N_2 = (\min(\delta_1, \delta_2), \max(X_1, X_2), \max(\nu_1, \nu_2)),$$

$$N_1 \cup N_2 = (\max(\delta_1, \delta_2), \min(X_1, X_2), \min(\nu_1, \nu_2)).$$

Definition 4. The basic operations of SVN are

$$N_1 \oplus N_2 = (\delta_1 + \delta_2 - \delta_1 \delta_2, X_1 X_2, \nu_1 \nu_2),$$

$$N_1 \ominus N_2 = (\delta_1 \delta_2, X_1 + X_2 - X_1 X_2, \nu_1 + \nu_2 - \nu_1 \nu_2),$$

$$\lambda N_1 = (1 - (1 - \delta_1)^\lambda, X_1^\lambda, \nu_1^\lambda),$$

$$N_1^\lambda = (\delta_1^\lambda, 1 - (1 - X_1)^\lambda, 1 - (1 - \nu_1)^\lambda).$$

Definition 5. The score function of an SVN is

$$S(N) = \delta - X - \nu,$$

and its accuracy function is

$$A(N) = \delta + X + \nu.$$

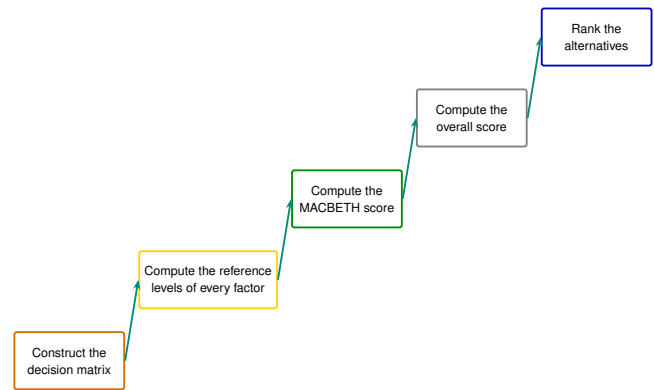


Figure 1. The steps of the MACBETH method.

3. MEASURING ATTRACTIVENESS BY A CATEGORICAL-BASED EVALUATION TECHNIQUE (MACBETH)

MACBETH was first created by Costa and Chagas. This approach determines the ranking by first setting the reference levels of each criterion and then computing the MACBETH score for each option. The following stages constitute the MACBETH technique [23, 24, 25, 26, 27]. This study uses an MCDM model with SVN to handle multiple criteria [28]. Figure 1 shows the steps of the proposed method.

Step 1. Construct the decision matrix with SVNS.

Step 2. Compute the reference levels of every factor:

$$r_j^+ = \max_i (x_{ij}), \quad (1)$$

$$r_j^- = \min_i (x_{ij}), \quad (2)$$

$$r_j^+ = \min_i (x_{ij}), \quad (3)$$

$$r_j^- = \max_i (x_{ij}). \quad (4)$$

Step 3. Compute the MACBETH score:

$$H_{ij} = S(r_k^+) + \frac{x_{ij} - r_j^-}{r_j^+ - r_j^-} [S(r_k^+) - S(r_k^-)], \quad (5)$$

where $S(r_k^+) = 100$ and $S(r_k^-) = 0$.

Step 4. Compute the overall score:

$$Y_i = \sum_{j=1}^n w_j \times H_{ij}. \quad (6)$$

4. RESULTS

Evaluating onshore wind farms involves considering various criteria related to efficiency, reliability, environmental impact, and economic feasibility. The following criteria are commonly used to assess onshore wind farms [29, 30, 31, 32, 33]:

1. **Wind Resource Assessment:** Conduct thorough assessments of wind speed, direction, and consistency at potential sites to ensure optimal turbine placement and maximum energy capture.
2. **Turbine Technology and Efficiency:** Evaluate the efficiency, size, and reliability of wind-turbine technology, considering factors such as rotor diameter, generator efficiency, and maintenance requirements.
3. **Capacity Factor and Energy Production:** Assess the capacity factor, which measures the actual energy production of a wind farm compared with its maximum potential output, to gauge its performance and efficiency.

4. **Grid Integration and Transmission Infrastructure:** Analyze the compatibility and integration of wind farms with existing power grids, ensuring efficient electricity transmission and grid stability.
5. **Environmental Impact Assessment:** Evaluate environmental implications, including impacts on wildlife, visual landscapes, noise pollution, and land use, to ensure minimal ecological disruption.
6. **Land Use and Site Suitability:** Assess land availability, local regulations, community preferences, and potential conflicts with other land uses to determine suitable locations for wind-farm development.
7. **Economic Viability and Cost-Effectiveness:** Conduct a cost-benefit analysis considering initial investment costs, operation and maintenance expenses, and the levelized cost of energy (LCOE) to determine economic feasibility.
8. **Community and Stakeholder Engagement:** Consider local community acceptance, stakeholder engagement, and social impacts to ensure that the project aligns with societal values and gains support from affected communities.
9. **Permitting and Regulatory Compliance:** Ensure compliance with legal and regulatory requirements, obtain the necessary permits, and adhere to environmental standards throughout the project lifecycle.
10. **Operational Performance and Reliability:** Monitor the operational performance, reliability, and downtime of wind turbines to ensure consistent and efficient energy generation over the project's lifetime.
11. **Lifetime and Decommissioning Planning:** Assess plans for turbine decommissioning and land restoration after the project lifespan, ensuring responsible and sustainable project closure.
12. **Health and Safety Standards:** Ensure adherence to health and safety standards for workers during wind-farm construction, maintenance, and operation.

By evaluating onshore wind farms using these criteria, stakeholders can make informed decisions regarding site selection, technology deployment, and project management, ultimately ensuring successful and sustainable wind-energy generation.

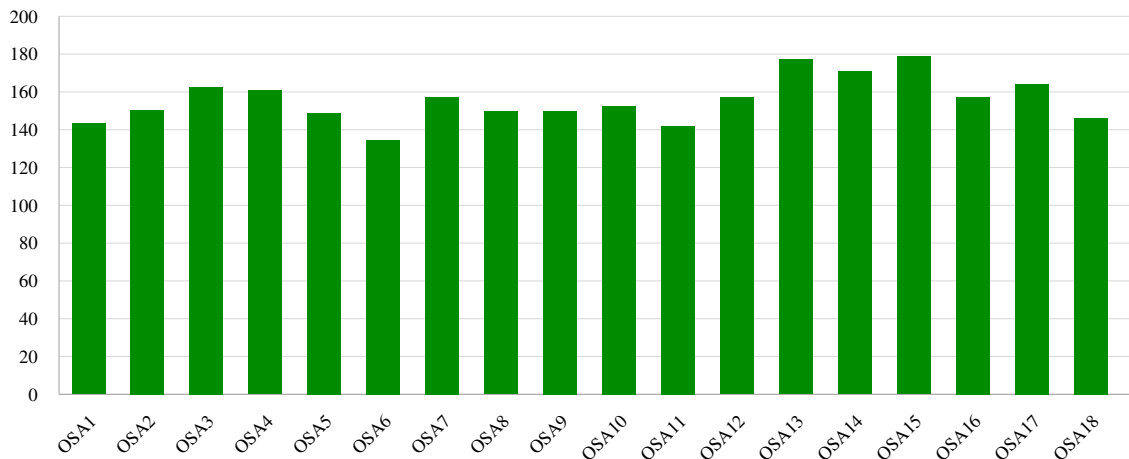
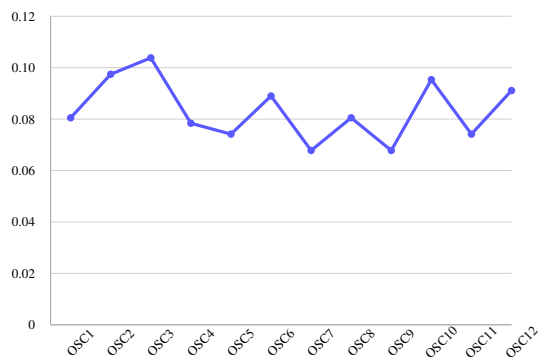


Figure 3. The rank of 18 alternatives in this study.

Table 1. The MACBETH score.

Alternative	OSC1	OSC2	OSC3	OSC4	OSC5	OSC6	OSC7	OSC8	OSC9	OSC10	OSC11	OSC12
OSA1	157.1429	200	185.7143	114.2857	116.6667	133.3333	157.1429	100	100	142.8571	157.1429	128.5714
OSA2	171.4286	171.4286	185.7143	171.4286	116.6667	133.3333	157.1429	100	100	142.8571	128.5714	200
OSA3	157.1429	185.7143	200	185.7143	166.6667	116.6667	142.8571	150	100	142.8571	200	185.7143
OSA4	200	200	185.7143	100	133.3333	200	157.1429	133.3333	100	157.1429	157.1429	171.4286
OSA5	142.8571	157.1429	171.4286	157.1429	133.3333	116.6667	100	150	200	200	114.2857	128.5714
OSA6	100	142.8571	128.5714	114.2857	100	150	100	150	185.7143	185.7143	100	142.8571
OSA7	114.2857	100	142.8571	185.7143	166.6667	200	142.8571	200	171.4286	171.4286	142.8571	157.1429
OSA8	157.1429	114.2857	100	157.1429	183.3333	150	185.7143	133.3333	128.5714	128.5714	185.7143	200
OSA9	142.8571	157.1429	114.2857	142.8571	133.3333	100	200	183.3333	142.8571	142.8571	171.4286	185.7143
OSA10	128.5714	142.8571	157.1429	128.5714	200	150	157.1429	133.3333	200	157.1429	128.5714	157.1429
OSA11	171.4286	128.5714	142.8571	171.4286	150	133.3333	185.7143	133.3333	157.1429	100	142.8571	114.2857
OSA12	185.7143	171.4286	128.5714	185.7143	200	183.3333	171.4286	166.6667	142.8571	114.2857	157.1429	100
OSA13	200	185.7143	171.4286	200	183.3333	200	142.8571	183.3333	100	200	200	142.8571
OSA14	142.8571	200	185.7143	185.7143	116.6667	166.6667	185.7143	200	157.1429	185.7143	185.7143	128.5714
OSA15	171.4286	185.7143	200	171.4286	183.3333	200	171.4286	183.3333	200	171.4286	142.8571	157.1429
OSA16	185.7143	171.4286	157.1429	157.1429	133.3333	116.6667	171.4286	183.3333	200	128.5714	157.1429	142.8571
OSA17	200	200	142.8571	185.7143	150	200	142.8571	183.3333	128.5714	142.8571	157.1429	128.5714
OSA18	157.1429	142.8571	128.5714	100	100	150	142.8571	116.6667	171.4286	185.7143	200	157.1429

Step 1. Construct the decision matrix between criteria and alternatives. The criteria weights are then computed using the mean method, as shown in Figure 2.

**Figure 2.** The criteria weights.

Step 2. Compute the reference levels of every factor for benefit and cost criteria using Eqs. (1)–(4).

Step 3. Compute the MACBETH score using Eq. (5), as shown in Table 1.

Step 4. Compute the overall score using Eq. (6), as shown in Table 2. The alternatives are then ranked as shown in Figure 3.

5. CONCLUSIONS

Evaluating onshore wind farms confirms their pivotal role in the global transition toward renewable energy sources. Technological advancements have promoted these wind farms, showcasing higher efficiency and reliability. Environmental assessments affirm their role in reducing greenhouse-gas emissions, albeit with considerations for ecological impacts and land use. Economic evaluations highlight decreasing costs and favorable trends in the levelized cost of energy, signaling a positive trajectory for wind-energy adoption. However, challenges persist, including intermittency concerns, upfront investment costs, and the need for enhanced grid infrastructure.

Table 2. The overall score.

Alternative	OSC1	OSC2	OSC3	OSC4	OSC5	OSC6	OSC7	OSC8	OSC9	OSC10	OSC11	OSC12
OSA1	12.65133	19.49153	19.27966	8.958838	8.65113	11.86441	10.65375	8.050847	6.779661	13.61985	11.65254	11.71308
OSA2	13.80145	16.70702	19.27966	13.43826	8.65113	11.86441	10.65375	8.050847	6.779661	13.61985	9.533898	18.22034
OSA3	12.65133	18.09927	20.76271	14.55811	12.35876	10.38136	9.68523	12.07627	6.779661	13.61985	14.83051	16.91889
OSA4	16.10169	19.49153	19.27966	7.838983	9.887006	17.79661	10.65375	10.73446	6.779661	14.98184	11.65254	15.61743
OSA5	11.50121	15.31477	17.79661	12.3184	9.887006	10.38136	6.779661	12.07627	13.55932	19.0678	8.474576	11.71308
OSA6	8.050847	13.92252	13.34746	8.958838	7.415254	13.34746	6.779661	12.07627	12.5908	17.70581	7.415254	13.01453
OSA7	9.200969	9.745763	14.83051	14.55811	12.35876	17.79661	9.68523	16.10169	11.62228	16.34383	10.59322	14.31598
OSA8	12.65133	11.13801	10.38136	12.3184	13.59463	13.34746	12.5908	10.73446	8.716707	12.25787	13.77119	18.22034
OSA9	11.50121	15.31477	11.86441	11.19855	9.887006	8.898305	13.55932	14.75989	9.68523	13.61985	12.71186	16.91889
OSA10	10.35109	13.92252	16.31356	10.07869	14.83051	13.34746	10.65375	10.73446	13.55932	14.98184	9.533898	14.31598
OSA11	13.80145	12.53027	14.83051	13.43826	11.12288	11.86441	12.5908	10.73446	10.65375	9.533898	10.59322	10.41162
OSA12	14.95157	16.70702	13.34746	14.55811	14.83051	16.31356	11.62228	13.41808	9.68523	10.89588	11.65254	9.110169
OSA13	16.10169	18.09927	17.79661	15.67797	13.59463	17.79661	9.68523	14.75989	6.779661	19.0678	14.83051	13.01453
OSA14	11.50121	19.49153	19.27966	14.55811	8.65113	14.83051	12.5908	16.10169	10.65375	17.70581	13.77119	11.71308
OSA15	13.80145	18.09927	20.76271	13.43826	13.59463	17.79661	11.62228	14.75989	13.55932	16.34383	10.59322	14.31598
OSA16	14.95157	16.70702	16.31356	12.3184	9.887006	10.38136	11.62228	14.75989	13.55932	12.25787	11.65254	13.01453
OSA17	16.10169	19.49153	14.83051	14.55811	11.12288	17.79661	9.68523	14.75989	8.716707	13.61985	11.65254	11.71308
OSA18	12.65133	13.92252	13.34746	7.838983	7.415254	13.34746	9.68523	9.392655	11.62228	17.70581	14.83051	14.31598

Moreover, social aspects such as community engagement and regulatory compliance emerge as critical determinants of successful wind-farm development. Addressing these challenges requires collaborative efforts among stakeholders, including governments, industry participants, and local communities. Strategic interventions in technological innovation, policy support, infrastructure development, and public engagement are imperative to unlock the full potential of onshore wind farms as a sustainable and integral component of the global energy mix. The MACBETH method was used as an MCDM model under SVNS to evaluate onshore wind farms. SVNS was used to address uncertain data in the evaluation process.

REFERENCES

- [1] J. M. Sánchez-Lozano, M. S. García-Cascales, and M. T. Lamata, "Identification and selection of potential sites for onshore wind farms development in region of murcia, spain," *Energy*, vol. 73, pp. 311–324, 2014.
- [2] B. K. Sovacool, P. Enevoldsen, C. Koch, and R. J. Barthelmie, "Cost performance and risk in the construction of offshore and onshore wind farms," *Wind Energy*, vol. 20, no. 5, pp. 891–908, 2017.
- [3] F. Haces-Fernandez, M. Cruz-Mendoza, and H. Li, "Onshore wind farm development: Technologies and layouts," *Energies*, vol. 15, no. 7, p. 2381, 2022.
- [4] P. Enevoldsen and S. V. Valentine, "Do onshore and offshore wind farm development patterns differ?" *Energy for Sustainable Development*, vol. 35, pp. 41–51, 2016.
- [5] X. Wu, W. Hu, Q. Huang, C. Chen, M. Z. Jacobson, and Z. Chen, "Optimizing the layout of onshore wind farms to minimize noise," *Applied Energy*, vol. 267, p. 114896, 2020.
- [6] D. Astolfi, F. Castellani, A. Garinei, and L. Terzi, "Data mining techniques for performance analysis of onshore wind farms," *Applied Energy*, vol. 148, pp. 220–233, 2015.
- [7] S. Grassi, S. Junghans, and M. Raubal, "Assessment of the wake effect on the energy production of onshore wind farms using GIS," *Applied Energy*, vol. 136, pp. 827–837, 2014.
- [8] X. Wu, W. Hu, Q. Huang, C. Chen, Z. Chen, and F. Blaabjerg, "Optimized placement of onshore wind farms considering topography," *Energies*, vol. 12, no. 15, p. 2944, 2019.
- [9] S. Carlos, A. Sánchez, S. Martorell, and I. Martón, "Onshore wind farms maintenance optimization using a stochastic model," *Mathematical and Computer Modelling*, vol. 57, no. 7–8, pp. 1884–1890, 2013.
- [10] S. Wang, S. Wang, and P. Smith, "Quantifying impacts of onshore wind farms on ecosystem services at local and global scales," *Renewable and Sustainable Energy Reviews*, vol. 52, pp. 1424–1428, 2015.
- [11] G. Ren, J. Liu, J. Wan, F. Li, Y. Guo, and D. Yu, "The analysis of turbulence intensity based on wind speed data in onshore wind farms," *Renewable Energy*, vol. 123, pp. 756–766, 2018.
- [12] P. W. Saługa, K. Zamasz, Z. Dacko-Pikiewicz, K. Szczepańska-Woszczyzna, and M. Malec, "Risk-adjusted discount rate and its components for onshore wind farms at the feasibility stage," *Energies*, vol. 14, no. 20, p. 6840, 2021.
- [13] J. R. F. Diógenes, J. Claro, J. C. Rodrigues, and M. V. Loureiro, "Barriers to onshore wind energy implementation: A systematic review," *Energy Research & Social Science*, vol. 60, p. 101337, 2020.
- [14] J. R. F. Diógenes, J. Claro, and J. C. Rodrigues, "Barriers to onshore wind farm implementation in brazil," *Energy Policy*, vol. 128, pp. 253–266, 2019.
- [15] J. Ye, S. Du, and R. Yong, "Multi-criteria decision-making model using trigonometric aggregation operators of single-valued neutrosophic credibility numbers," *Information Sciences*, vol. 644, p. 118968, 2023.
- [16] S. Debnath, "Single-valued neutrosophic covering-based rough set model over two universes and its application in MCDM," *Neutrosophic Sets and Systems*, vol. 53, no. 1, p. 29, 2023.
- [17] X. Luo, Z. Wang, L. Yang, L. Lu, and S. Hu, "Sustainable supplier selection based on VIKOR with single-valued neutrosophic sets," *PLOS ONE*, vol. 18, no. 9, p. e0290093, 2023.
- [18] H. Ran, "MABAC method for multiple attribute group decision making under single-valued neutrosophic sets and applications to performance evaluation of sustainable microfinance groups lending," *PLOS ONE*, vol. 18, no. 1, p. e0280239, 2023.
- [19] K. M. Sallam and A. W. Mohamed, "Single valued neutrosophic sets for assessment quality of suppliers under uncertainty environment," *Multicriteria Algorithms with Applications*, vol. 1, no. 1, pp. 1–10, 2023.
- [20] G. Ramya, "Trigonometric similarity measures of pythagorean neutrosophic hypersoft sets," *Neutrosophic Systems with Applications*, vol. 9, pp. 91–100, 2023.
- [21] P. K. Singh, "Uncertainty analysis in document publications using single-valued neutrosophic set and collaborative entropy," *Artificial Intelligence Review*, vol. 56, no. 3, pp. 2785–2809, 2023.
- [22] Y. Li, Q. Cai, and G. Wei, "PT-TOPSIS methods for multi-attribute group decision making under single-valued neutrosophic sets," *International Journal of Knowledge-Based and Intelligent Engineering Systems*, vol. 27, no. 2, pp. 149–166, 2023.
- [23] T. R. Bastos, A. A. Longaray, C. M. dos Santos Machado, L. Ensslin, S. R. Ensslin, and A. Dutra, "Fuzzy-MACBETH hybrid method: Mathematical treatment of a qualitative scale using the fuzzy theory," *International Journal of Computational Intelligence Systems*, vol. 16, p. 21, 2023.

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- [24] S. O. Adebisi, E. O. Kupolati, and O. G. Oyenuga, "Measuring attractiveness by a categorical based evaluation technique (MACBETH) for churn and retention of decision of subscribers in the nigeria telecommunication industry," *International Journal of Applied Operational Research—An Open Access Journal*, vol. 11, no. 2, pp. 33–44, 2023.
- [25] N. Kundakcı, "Combined multi-criteria decision making approach based on MACBETH and MULTI-MOORA methods," *Alphanumeric Journal*, vol. 4, no. 1, pp. 17–26, 2016.
- [26] P. Karande and S. Chakraborty, "A facility layout selection model using MACBETH method," in *Proceedings of the 2014 International Conference on Industrial Engineering and Operations Management*, Bali, Indonesia, January 7–9 2014.
- [27] N. Kundakcı, "An integrated method using MACBETH and EDAS methods for evaluating steam boiler alternatives," *Journal of Multi-Criteria Decision Analysis*, vol. 26, no. 1–2, pp. 27–34, 2019.
- [28] M. Mohamed, "Toward smart logistics: Hybrization of intelligence techniques of machine learning and multi-criteria decision-making in logistics 5.0," *Multicriteria Algorithms with Applications*, vol. 1, no. 1, pp. 42–57, 2023.
- [29] E. Phimister and D. Roberts, "The role of ownership in determining the rural economic benefits of on-shore wind farms," *Journal of Agricultural Economics*, vol. 63, no. 2, pp. 331–360, 2012.
- [30] K. F. Sotiropoulou and A. P. Vavatsikos, "Onshore wind farms GIS-assisted suitability analysis using PROMETHEE II," *Energy Policy*, vol. 158, p. 112531, 2021.
- [31] S. Wharton and J. K. Lundquist, "Assessing atmospheric stability and its impacts on rotor-disk wind characteristics at an onshore wind farm," *Wind Energy*, vol. 15, no. 4, pp. 525–546, 2012.
- [32] J. F. Unnewehr, E. Jalbout, C. Jung, D. Schindler, and A. Weidlich, "Getting more with less? why repowering onshore wind farms does not always lead to more wind power generation—a german case study," *Renewable Energy*, vol. 180, pp. 245–257, 2021.
- [33] K. B. Oebels and S. Pacca, "Life cycle assessment of an onshore wind farm located at the northeastern coast of brazil," *Renewable Energy*, vol. 53, pp. 60–70, 2013.
-