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Assessing wind farms projects with the use of multicriteria methods and stakeholders analysis

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Abstract The use of wind potential and the protection of biodiversity are two conflicting aspects that arise in the development of wind energy projects, generating conflicts between different stakeholders. The aim of this study is to develop a methodology for assessing the suitability of existing wind farms in mountainous areas with the combined use of Analytical Hierarchy Process (AHP), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method and Stakeholders Analysis. The application is carried out in the Regional Unit of Ioannina. Twelve assessment criteria have been considered in the analysis and fourteen selected stakeholders have participated in their pairwise comparisons. Four different alternative scenarios are formulated based on the power/interest matrix of stakeholder mapping. The prioritization of the existing wind farms is finally carried out with the use of TOPSIS method for each alternative scenario. The results showed that, for two scenarios the ideal wind farm is located in Variko, while for the other two, the ideal wind farm is located in Katara. The proposed methodology is able to promote spatial energy planning, emphasize the key components of the decision problem, and award participating decisions through a multi-stakeholder traceable and transparent assessment procedure.

Keywords: ***AHP, Participated decision-making process, TOPSIS, stakeholders mapping, wind farms***

1. Introduction

Almost 1.3 billion people, or 30% of the world's urban population, were covered by renewable energy targets and/or regulations by the end of 2021 in about 1,500 cities (REN21, 2022). A significant contribution to achieving a low-carbon or entirely carbon-free energy factor is made by wind energy (Spyridonidou & Vagiona, 2020).

The aim of the present research is to assess the suitability of the existing wind farms in the Regional Unit of Ioannina through the combined use of the Analytic Hierarchy Process (AHP) (Saaty, 1980) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method (Hwang and Yoon, 1981), as Multicriteria Analysis (MCA) methods, and the stakeholders mapping (Mendelow, 1981), with the use of power/interest matrix as part of stakeholders analysis. It should be noted that the combined use of Multicriteria Evaluation and Stakeholders Analysis has been considered in other sectors such as hydropower management and waste management (Rosso et al., 2014; Geneletti, 2010; Shen et al., 2012). However, to the authors' knowledge, no application of integrating AHP, TOPSIS and Stakeholders Analysis in energy planning related issues can be found. Therefore, the novelty of the present investigation is the combined use of MCA and Stakeholders Analysis concerning the spatial planning of wind farms.

The remainder of the paper is organized as follows. Section 2 describes the methodological framework of assessing the suitability of existing wind farms, presenting both the exclusion and the evaluation criteria considered in the current analysis. In Section 3, the results are presented and discussed, while, in Section 4, the main conclusions are drawn.

2. Materials and Methods

The methodological framework consists of four phases. The first phase includes the fulfillment of nine exclusion criteria (Phase I). This is achieved using Geographical Information System (GIS) in order to create thematic maps considering nine (9) exclusion criteria. Twelve (12) assessment criteria are further selected in order to assess the suitability of the existing wind farms in the Regional Unit of Ioannina (Phase II). In the present paper, a multicriteria decision making model (combined use of AHP and TOPSIS) (Phase III) and Stakeholders Analysis (Phase IV), is used to prioritize the existing wind farms in the Regional Unit of Ioannina. The theory of AHP is based on the following steps: breaking down the decision – problem; pairwise comparisons of various criteria and alternatives; synthesis of the preferences (Saaty, 2006). TOPSIS is a simple and computationally efficient multiple-criteria decision-making (MCDM) technique that selects the best solution from a pool of solutions. It follows several steps that are clearly described in Chen and Hwang (1992), with reference to Hwang and Yoon (1981). The selected solution must have the smallest geometric distance from the positive ideal solution and the biggest from the negative ideal solution, according to the TOPSIS approach (Nikas et al, 2018). Stakeholders Analysis is selected for the identification and classification of the stakeholder group who can affect and be affected by the realization of organizational goals (Rosso et al., 2014).

2.1. Exclusion and Assessment Criteria

Regarding the spatial energy planning process, a fundamental step is the proper choice of the exclusion as well as the assessment criteria. Hence, nine exclusion and twelve assessment criteria are included in the analysis for the suitability of existing WFs in mountainous areas (Table 1).

Table 1: Assessment and Exclusion Criteria.

Assessment Criteria	**Exclusion Criteria**
(AC1): Wind Potential	(EC1): Distance from Protected Areas
(AC2): Areas of Environmental Interest	(EC2): Distance from Wildlife Refuges
(AC3): Military Zones	(EC3): Distance from National Parks
(AC4): Social Acceptance	(EC4): Distance from Forest Lands
(AC5): Proximity to the High Voltage Electricity Grid	(EC5): Distance from Settlements
(AC6): Proximity to the Road Network	(EC6): Distance from Road Network
(AC7): Ground Slope	(EC7): Distance from Electricity Transmission System
(AC8): Altitude	(EC8): Distance from Archeological & Cultural Sites
(AC9): Proximity to the Airports	(EC9): Distance from Airports
(AC10): Proximity to Water Surfaces	
(AC11): Proximity to Forest Lands	
(AC12): Tourist Zones	

2.2. Stakeholders

The cooperation of different actors with conflicting objectives and interests is a prerequisite for the deployment and management of wind energy projects. Thus, the aspects of all stakeholders for the proper decision – making process should be considered (Roy, 1990). Table 2 presents the relevant stakeholders included in the analysis and their percentage of importance in the decision – making process. It should be noted that the percentage of importance is derived from the Power/Interest Matrix, by multiplying the level of the stakeholders' power with the level of their interest using a ten-point Likert scale (1: low power/interest and 10: high power/interest). The assessment of their power and interest is based on the authors' judgments.

Table 2: Most relevant stakeholders for the existing WFs and importance of them in the decision problem.

Number	Stakeholders	Level	Percentage of Importance (%)
1	Regulatory Authority for Energy	National / Regional	1.0
2	Owner	Provincial / Local	1.0
3	Construction Company	Provincial / Local	1.0
4	Project Construction Study Group	Provincial / Local	0.48
5	Environmental Impact Researcher	Provincial / Local	0.8
6	Ministry of Environment and Energy	National	0.48
7	Ministry of Rural Development and Food	National	0.1
8	Ministry of Culture and Sports	National	0.15
9	Ministry of Infrastructure, Transport and Networks	National	0.15
10	Ministry of Defense	National	0.09
11	Regional Council	Regional	0.1
12	City Council	Local	0.06
13	Decentralized Management of Environmental Projects	Regional	0.24
14	Hellenic Electricity Distribution Network Operator	National / Regional	0.9

3. Results

After defining the assessment criteria, pairwise comparisons are performed, using the Saaty's scale to quantify their relative weights. Four different scenarios are deployed based on the assessment of different stakeholders' groups (Ackermann and Eden, 2011), namely: S1. Players (high power, high interest), S2. Subjects (low power, high interest), S3. Context Setters (high power, low interest), and S4. Crowds (low power, low interest). The relative weights of the assessment criteria under all the performed scenarios are presented in Figure 1, using the computations of the AHP method, while Table 3 presents the positive ($\boldsymbol{S}^{+}$) and negative ($\boldsymbol{S}^{-}$) ideal solutions as well as the relative closeness ($\boldsymbol{C}_i^{+}$) to the positive ideal and the negative ideal solution of the examined existing wind farms (A1: Kasidiaris I, A2: Kasidiaris II, A3: Variko and A4: Katara) under the four different scenarios using the computations of the TOPSIS method.

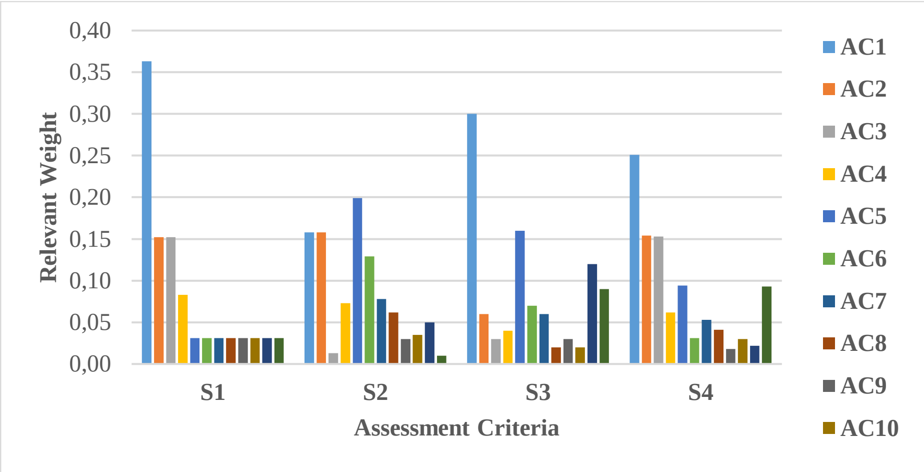

Figure 1. Assessment weights for different scenarios.

Table 3: Ideal solutions and relative closeness for the performed scenarios (S1–S4).

		Si+	Si-	Pi			Si+	Si-	Pi
S1: Stakeholders Group I Players	**A1**	0.039	0.030	0.435	**S3: Stakeholders Group III Context Setters**	**A1**	0.047	0.036	0.439
	A2	0.040	0.027	0.402		**A2**	0.044	0.030	0.407
	A3	0.033	0.029	0.465		**A3**	0.027	0.046	0.629
	A4	0.023	0.041	0.634		**A4**	0.038	0.036	0.488
S2: Stakeholders Group II Subjects	**A1**	0.066	0.038	0.368	**S4: Stakeholders Group IV Crowd**	**A1**	0.032	0.032	0.494
	A2	0.048	0.039	0.444		**A2**	0.034	0.027	0.440
	A3	0.028	0.069	0.711		**A3**	0.031	0.029	0.483
	A4	0.047	0.037	0.444		**A4**	0.026	0.031	0.547

Figure 1 illustrates how each scenario has a significant impact on the relative weights of the assessment criteria. Based on the results from Table 3, for two scenarios (S2 and S3) the ideal wind farm is located in Variko (A3), while for the other two (S1 and S4), the ideal wind farm is located in Katara (A4).

4. Conclusions

In conclusion, this paper presents a methodological framework that can contribute to decision - making related to the complex issue of wind farm sitting. The final outcome is a ranking of the alternatives for all the relevant stakeholder groups. The model includes numerous exclusion and assessment criteria that can be found either in the current national legal framework or in the international scientific literature and support sustainable development. An advantage, that arises from the implementation of the AHP and TOPSIS, is that the most appropriate elements should put in evidence in order to be considered with the aim of setting guidelines for the design and operation of wind farms. One of the most significant advantage of the applied methodological framework is that the decision makers acquire more knowledge of the parameters of the analysis through the whole process. Thus, they can thoroughly learn about the problems while solving them. Stakeholders Analysis contributes to the involvement of all relevant stakeholders and the consideration of their judgments according to their power and interest. A disadvantage of the methodology is that the high number of comparisons in the AHP method frequently confuses the stakeholders who are not familiar with this method. Finally, the proposed methodological framework can be further validated in other spatial planning decision making problems.

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