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Proceeding Paper

Application of Multi-Criteria Analysis in the EIA †

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Abstract: Impact Assessment (EIA) is an instrument of sustainable development. This paper focuses on the selection between technological variants of an investment in the Environmental Impact Assessment as a base material, using a different method than the original. The author selects the optimal technological variant using the MCDA methods with a hybrid approach, combining the AHP method to determine the criteria weights, as well as the TOPSIS method to create the variant ranking. The results are compared.

Keywords: EIA; MCDA; TOPSIS; AHP; sustainable development

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1. Introduction

Environmental Impact Assessment (EIA) is an instrument of sustainable development because it creates methodical and procedural basics to assess methodological and procedural foundations for including environmental protection issues in the development planning process. EIA allows predicting and thus avoiding, minimizing, mitigating or (as a last resort) compensating for significant negative environmental impacts; it creates conditions for preserving the value (also social and economic) and productivity of ecosystems and maintaining the functions they perform. RES (renewable energy sources) are important tools supporting sustainable development [1].

Currently, there are solar, wind, hydro, biomass, and geothermal energy that are considered desirable as they are free of CO_2 emissions as well as of pollution [2]. "Poland's energy policy until 2040" is one of the strategies of "Strategy for Responsible Development" that is aiming to create the basics to transform the existing economy towards a low-carbon economy. This document assumes a greater share of RES in electricity generation, such as wind energy, with the use of wind farms [3]. Therefore, the impact of wind power generation in the power system is of great importance.

Many investments require an EIA, even those related to renewable energy sources. The aim of this paper is to select the optimal technological variant of a wind farm out of the two alternatives with the use of multi-criteria decision aid methods.

2. Materials and Methods

The assessment will be carried out based on EIA of a wind farm in Adamów, Poland, in 2012 (supplementary materials). The document consists of many criteria that the author sorted out and chose those that depict the problem in the optimal way. The designed wind farm will be equipped with 10 wind farms of the company.

The first variant (A1) is an installation of GE Wind turbines with energy type GE 1.5sle with a power of 1.5 MW each, mounted on masts with a height of 100 m.

Alternative 2 (A2) describes a wind farm with the ENERCON GmbH type E-82 2 MW devices mounted on masts with a height of 108 m. They are one of the most modern solutions and are used all over the world, being part of the largest wind parks. The producer of the ENERCON E-82 power plant guarantees that the power level acoustic turbine will not exceed 104 dB.

There are many methods of assessing the environmental impact of an investment. Each of them is helpful in determining the most favorable decision variant, it needs to be adjusted to the decision problem. Multi-criteria decision methods (MCDM/MCDA) in the EIA are widely used as they are universally applicable and they can be adapted to many decision problems [4].

The analysis starts with the selection of decision variants that will be analyzed. The next step is the appropriate selection of criteria so that they provide a lot of information for the analysis. They are unique and constitute a good representation of the criteria from their group. The criteria should be ranked by assigning weights to them, and then they can be defined as stimulants and destimulants [5].

2.1. Criteria Selection

In decision-making situations, when the subject of assessment describes more than a few criteria, the analysis of the initially adopted set is troublesome, especially in terms of the mutual relations between the attributes. In this case, it is recommended to use a matrix and a criteria graph.

The construction of the criteria matrix G (n + 1, n + 1), where n—the number of criteria, is performed by analyzing each pair of attributes C_i, C_j ($i \neq j$) in terms of the information they give about the assessed solution. If this information coincides even partially, then the direction of this relationship is examined. On the basis of the developed matrix, a graph of criteria was built (Figure 1). It is illustrating the mutual relations between the criteria. All 11 criteria connected to Global Criteria (environmental impact) from the EIA wind farm were analyzed. The number of arcs entering each criterion (vertex) of the graph was calculated and based on it, the attributes used in this assessment were chosen.

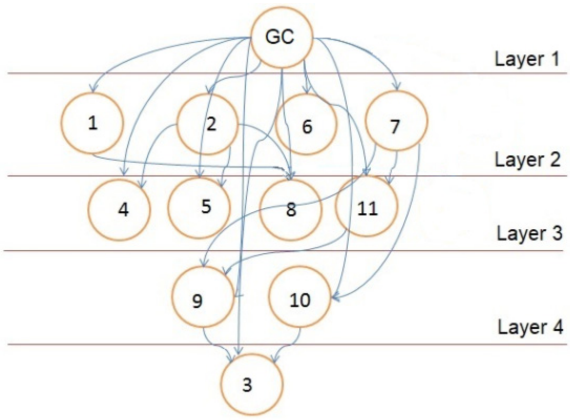

Figure 1. Layer-ordered criteria graph GC—Global Criteria. Source: own work.

For the final set of criteria, all the criteria connected only with the graph vertex or with the global GC criterion are adopted. That is (renumbered sequentially by the author as C1–C5 criteria):

- C6—nominal output power, (as of now C1)—stimulant;in addition to the above-mentioned criterion, the criteria located in one of the layers with the largest number of vertices were adopted. These are the criteria from Layer 2;
- C4—blade diameter (as of now C2)—stimulant;
- C5—sweep area (as of now C3)—destimulant;
- C8—number of wind turbine gearboxes (as of now C4)—stimulant;
- C11—nominal wind speed (as of now C5)—stimulant.

2.2. AHP Method

One of the methods of analytical hierarchy is the AHP (Analytical Hierarchy Process) method. It allows pairs of criteria to be compared with each other, and then, the decision variants can be compared. This enables the creation of a scale vector and the selection of the most favourable decision alternative. Comparisons are made using a 9-grade rating steel [6]. The AHP method is based on the decomposition of a complex decision problem, with smaller hierarchical structures (goals, criteria, and variants) [7].

In this analysis, weights of the mentioned attributes were estimated using the AHP method (Figure 2). As seen on the graph, both nominal output power (C1) and sweep area (C3) rank as number 1, as the most important (they weight the most).

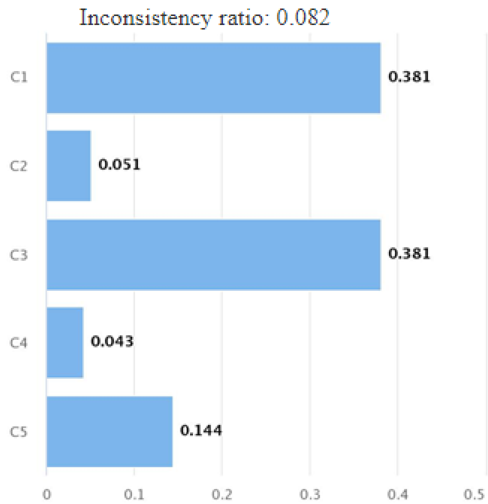

Figure 2. Estimated criteria weights using AHP method. Source: own work.

2.3. TOPSIS Method

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) consists of seven phases that end with a clear ranking of the analyzed variants. It is used to solve multi-criteria discrete tasks. In the TOPSIS procedure, the considered decision alternatives are compared not with other variants, but with weighted reference solutions: the ideal solution (thesis) as well as the anti-ideal solution (antithesis) [8,9]. The alternatives were evaluated with the set of weights estimated using the AHP method. This way, the final ranking of the variants was created (Table 1).

Table 1. The final rank for alternatives using TOPSIS method (first approach); R_i—global rating.

	R_i	Final Rank
A1	0.2597900296653669	2
A2	0.740209970334633	1

3. Results

The ranking in Table 1 shows that the second analyzed variant is preferable and should be chosen. This variant represents the devices of higher power (2 MW in comparison to 1.5 MW in alternative 1); it is a modern and well-known product, a wind turbine used all over the world.

Of course, the result depends on the chosen criteria and the heir weights and this is connected to the influence of the decision maker's preferences.

The hybrid approach the author chose, combining the AHP method, to determine the criteria weights, with the TOPSIS method, made it easy in the decision-making to choose the most optimal variant. This approach can be used in many evaluations, especially in EIA.

4. Discussion

The use of renewable energy sources is one of the elements of the implementation of the sustainable development strategy. Clean energy sources are the future of acquiring energy. The analysis carried out in the original EIA showed a similar result to the one carried out by the author. The methods used by them were however different. This proves, that the AHP-TOPSIS hybrid approach can be generally used in such assessments.

The hybrid approach is an easy way to consider both the weight of criteria, as well as carrying out the whole evaluation of the variants. More research is needed to determine if another mix of methods, e.g., AHP and PROMETHEE, ELECTRE, BIPOLAR, etc., could be used in the same way, but the assessment surely reflects the potential of this approach.

Investments of renewable energy sources offer a real chance to reduce fossil fuels in the future. However, they are complex, and we should look at them holistically. This is why another analysis should also be performed to find the best location to place the wind turbine farm. It is also important to carry out a complex Life Cycle Assessment (LCA) for the objective results.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/environsciproc2022018011/s1, Environmental Impact Assessment of a project consisting in building a wind farm in Adamów, commune Gronowo Elblaskie, 2012, Gdańsk.

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