Evaluating the Importance of Key Success Factors for Installing Solar Plants

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Abstract: - Solar energy is one of the cleanest and most widely used energy type in the world. The installation of solar energy power plants is very costly and it is not possible to change the area then. Thus, it is very important to choose the area where the power plant will be installed correctly. In this study, analytic network process (ANP) is employed to find the importance of key success factors for installing solar plants in the right area. The success factors are determined by reviewing the literature and by obtaining the experts opinions.

Key-Words: - Analytic network process, location selection, multi-criteria decision making, renewable energy, solar energy, success factors.

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1 Introduction

Solar energy, one of the renewable energy sources, is one of the cleanest and most widely used energy types. Solar power plants are available to convert solar energy into usable energy. Although all solar power plant components can be replaced at a certain cost, it is not possible to change the area later, that is, to move the plant to another area. Thus, it is very important to choose the area where the power plant will be installed correctly.

Today, the use of solar energy is becoming widespread in the world. The main goal of this study is to contribute to the more efficient and effective use of solar power plants by determining the importance of key success factors for installing solar plants in the right area. In this way, our rate of benefiting from solar energy will increase and it will contribute to the establishment of a more self-sufficient system in energy.

In the literature, researchers are employed different methods for solar energy power plant installation in Türkiye. Uyan [1] employed geographic information system (GIS) and analytic hierarchy process (AHP). Ozcan et al. [2] combined analytic network process (ANP) and technique for order preference by similarity to ideal solution (TOPSIS). Yousefi et al. [3] used GIS based fuzzy boolean logic model. Goh et al. [4] employed cost-benefit analysis analysis. Khorsidi et al. [5] integrated fuzzy decision-making trial and evaluation laboratory (DEMATEL) method and fuzzy multi-objective optimization based on ratio analysis (MOORA) method.

In this study, ANP method is employed to find the importance of key success factors for installing solar plants in the right area. The success factors are determined by reviewing the literature and by obtaining the experts opinions. The rest of the study is organized as follows. ANP method is explained in Section 2. Case study is illustrated in the third Section. Finally, conclusions are provided in the last Section.

2 Analytic Network Process

ANP is a general form of AHP used in multi-criteria decision analysis developed by Thomas L. Saaty in 1980 [6]. ANP, which is a technique that can be used in multi-criteria decision-making problems, employed to analyze a complex process to find component weights, i.e., vectors of relative importance. The application steps of the ANP is as follows [7]:

Step 1: Identification of the problem and creation of the model.

Step 2: Determination of criteria and their relationships.

Step 3: The importance scale from 1 to 9 suggested by Thomas L. Saaty [6] given in Table 1 is used to create pairwise comparison matrices.

Table 1. Scale of significance used in pairwise comparisons [6]

Value	Definition	Explanation
1	Of equal importance	Both criteria are equally important.
3	Moderately more important	Judgments and experiences make one criterion a little more important than another.
5	Strongly or substantially more important	Judgments and experiences make one criterion very important over another.
7	Very strong or demonstrated importance	One criterion is strongly superior to another.
9	Extremely more important	Judgments and experience show that one criterion is extremely superior to another.
2, 4, 6, 8	Intermediate values of the judgment	Intermediate numbers are used if necessary.

Step 4: The consistency of pairwise comparisons made with the help of experts is determined by calculating Consistency Rate (CR) for each matrix. For pairwise comparisons to be consistent, the consistency ratio must be less than or equal to 0.10. Otherwise, comparisons should be reviewed. To calculate the CR value, it is necessary to know the Consistency Index (CI). CI is calculated as follows (Ömürbek et al., 2014):

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (1)$$

The largest value among the eigenvalues of a square matrix is expressed by λ_{max}. In order to calculate λ_{max}, each element of the entire priority matrix is divided by the elements of the priority vector, and the new matrix elements obtained are averaged.

The appropriate value is selected according to Table 2 showing the values of Random Index (RI) and CR is calculated with the following formula:

$$CR = \frac{CI}{RI} \quad (2)$$

Table 2. RI values

Number Of Decision Options (n)	RI
1	0.00
2	0.00
3	0.58
4	0.9
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49
11	1.51
12	1.48
13	1.56
14	1.57
15	1.59

Step 5: Create and analyze super matrices.
Step 6: Find the weights of the alternatives.

3 Case Study

The key success factors for installing solar plants are determined as solar radiation, heat, altitude, slope, distance to roads, and distance to transformer center, by reviewing the literature and by the experts opinions.

In the next step, pairwise comparisons of the criteria are made. Table 1 is taken as reference during the scoring. Moreover, the scores are created with the joint opinions of several experts. These scores then formed a matrix. This matrix is called super matrix as mentioned before. Also, the app checked the CR value which is 0.07530, which means it has an acceptable inconsistency as it is less than 0.1. The super matrix created before normalization is given in Table 3.

The resulting super matrix is first normalized by the software. After normalization, the limit super matrix is obtained by taking the power of the super matrix by the software. The weights of the criteria were found with the super limit matrix. The final weights obtained are given in Table 4.

Table 4. Importance of key success factors

Criteria	**Weights**
Solar Radiation	0.38741
Heat	0.22418
Altitude	0.06842
Slope	0.16956
Distance To Roads	0.03825
Distance To Transformer Centers	0.11219

Table 3. The super matrix before normalization

Criteria	Solar Radiation	Heat	Altitude	Slope	Distance To Roads	Distance To Transformer Centers
Solar Radiation	1	4	3	2	6	4
Heat	1/4	1	3	3	5	2
Altitude	1/3	1/3	1	1/3	2	1/3
Slope	1/2	1/3	3	1	6	2
Distance To Roads	1/6	1/5	1/2	1/6	1	1/3
Distance To Transformer Centers	1/4	1/2	3	1/2	3	1
Total	2.50	6.36	13.50	7.00	23.00	9.66

It is seen form Table 4 that the most important key success factor is solar radiation followed by heat. Distance to roads is determined as the least important criteria. Considering the reality of the design presented in the study, it can be said that the determination of the performance criteria and their weightings following the ANP are realistic. Their ratings of the performance criteria, which were created by taking input from a few energy industry experts, were consistent. Additionally, specialists; they have the idea that the performance indicators used in the project are among the most critical performance indicators for the installation of the solar power plant.

4 Conclusion

In this study, ANP method is employed to find the importance of key success factors for installing solar plants in the right area. The success factors are determined by reviewing the literature and by obtaining the experts opinions. According to the results of the ANP method, the most important performance indicator is solar radiation. Next comes the heat. Third, the slope. Fourth, the distance to transformation centers. Then comes the altitude and finally the distance to the roads.

It is possible that this work can be improved in the future. Various assumptions have been made to more clearly interpret the results of this study and to facilitate certain treatments. Cost elements can be added numerically so that this study can be used more widely. In this study, cost factors are considered to have only negative effects. Moreover, the selection of solar power plant location considering the obtained results can be the subject of the future researches.

References:

[1] Uyan, M., Güneş enerjisi santrali kurulabilecek alanların AHP yöntemi kullanılarak CBS destekli haritalanması, *Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi*, Vol. 23, No. 4, 2017, 343-351.

[2] Ozcan, E. C., Unlüsoy, S., Eren, T., ANP ve TOPSIS yöntemleriyle Türkiye'de yenilenebilir enerji yatırım alternatiflerinin değerlendirilmesi, *Selçuk Üniversitesi Mühendislik, Bilim Ve Teknoloji Dergisi*, Vol. 5, No. 2, 2017, 204-219.

[3] Yousefi, H., Hafeznia, H., Yousefi-Sahzabi, A., Spatial site selection for solar power plants using a GIS-based boolean-fuzzy logic model: a case study of Markazi province, Iran, *Energies*, Vol. 11, No. 7, 2018, 1648.

[4] Goh, H. H., Li, C., Zhang, D., Dai, W., Lim, C. S., Kurniawan, T. A., Goh, K.C., Application of choosing by advantages to determine the optimal site for solar power plants, *Scientific Reports*, Vol. 12, 2022, 4113.

[5] Khorshidi, M., Erkayman, B., Albayrak, O., Kılıç, R., Demir, H. I., Solar power plant location selection using integrated fuzzy dematel and fuzzy MOORA method, *International Journal of Ambient Energy*, Vol. 43, 2022, 7400-7409.

[6] Saaty, T. L., The analytic hierarchy process, McGraw-Hill, New York, 1980.

[7] Kheybari, S., Rezaie, F. M., Farazmand, H., Analytic network process: An overview of applications, Applied Mathematics and Computation, Vol. 367, 2020, 124780.

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

Mehmet Salih Degirmenci and Mehtap Dursun designed the study.
Mehmet Salih Degirmenci and Mehtap Dursun conducted the computations.
Mehtap Dursun and Nazli Goker analysed the results and write the manuscript.

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Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.