

Decision Support System for Determining Critical Land in Klaten Regency

Yudi Eko Windarto^{1*}, Nurhadi Bashit², Novia Sari Ristianti³, Desyta Ulfiana⁴, Devina Trisnawati⁵

¹Department of Computer Engineering, Faculty of Engineering, Diponegoro University, Indonesia

²Department of Geodetic Engineering, Faculty of Engineering, Diponegoro University, Indonesia

³Department of Urban and Regional Planning Engineering, Faculty of Engineering, Diponegoro University, Indonesia

⁴Department of Civil Engineering, Faculty of Engineering, Diponegoro University, Indonesia

⁵Department of Geological Engineering, Faculty of Engineering, Diponegoro University, Indonesia

Abstract. Critical land has become a problem in the world. Critical land is very detrimental to the health of the land. Several factors cause the land to become critical. One of them is the use of land that is not by the capabilities of the land. If no repairs made, the land will be physically, chemically, and biologically damaged. Klaten Regency is one of the regencies in Central Java Province, which has quite extensive critical land. It is necessary to monitor and improve land quality regularly to avoid critical land problems. Data and information on critical land obtained from Klaten Regency processed into a decision support system. Decision Support System uses a combination of Analytical Hierarchy Process (AHP) and Technique For Order Preference by Similarity to Ideal Solution (TOPSIS) methods. In this research, a Web-based Decision Support System created to determine the critical land area in Klaten Regency. The information system created has an alternative menu and criteria that determine the potential of critical land in Klaten Regency, making it easier for users to obtain information.

Keywords. Critical Land, Data, Information, and Decision Support System

1. Introduction

Critical land becomes a problem in data processing in the environmental field[1, 2]. Regional Development Planning Agency Klaten Regency has difficulty in determining critical land. This is due to various parameter values and criteria. So we need a system that can provide information about critical land in Klaten Regency accurately, effectively and

* Corresponding author: yudi@live.undip.ac.id

efficiently. Therefore, the system created can assist the Regional Development Planning Agency Klaten Regency in making decisions to determine the potential for critical land in accordance with existing criteria. This study uses 6 criteria in determining Critical Land. These criteria include slope, land use, geology, rainfall, hidrogeology and soil types. Alternatively there are 26 subdistricts including Pedan, Karangdowo, Karanganom, Jatinom, Ngawen, Juwiring, Manisrenggo, Kalikotes, Ceper, Trucuk, Prambanan, Jogonalan, Bayat, Cawas, Delanggu, Kemalang, Tulung, Polanharjo, Wonosari, Karangnongko, Gantiwarno, Klaten Utara, Klaten Tengah, Klaten Selatan, Kebonarum, Wedi. The implementation of Analytic Hierarchy Process (AHP) and Technique For Order Preference by Similarity to Ideal Solution (TOPSIS) methods as a Decision Support System will provide more effective and efficient processing of this data and can be used as a mapping illustration in an area to determine critical land.

2. Literature Review

Utilizing AHP method was previously used to rank options according to the relevance of the criteria weights for delineation of groundwater potential zones[3]. AHP method is a decision making method to calculate priority criteria that meet the requirements of several alternatives based on the judgment of the decision maker[4, 5]. Although the AHP method has several advantages, it cannot be separated from the shortcomings, the method is less effective if it is used in cases that have a large number of criteria and alternatives. Other methods are needed to be combined in order to obtain more effective results [6-8]. AHP when used to rank requires a relatively longer time and only compares between criteria, there is no normalization process and calculation of its costs and benefits [9, 10, 12]. The AHP method is also used to choosing the optimal technology to rehabilitate the pipes in water distribution systems[13]. TOPSIS is a multi-criteria method used to identify solutions from alternative sets based on simultaneous minimization of ideal point distances and maximizing distances from low points [14-17].

3. Research Methodology

In this study using the Analytic Hierarchy Process (AHP) method, will be calculated from the criteria weight value to obtain a total priority value (tpv), which will then be used in calculations with the Technique For Order Preference by Similarity to Ideal Solution (TOPSIS) method.

3.1 Criteria Weights

First we need criteria data which contains the weights which in this case are 6 influential criteria obtained from the Klaten Regency field. These data are shown in the table 1.

Table 1. Parameters and values data

Criteria	Value	Explanation
Slope	5	Benefit
Land Use	7	Benefit
Geology	3	Benefit
Rainfall	5	Cost
Hidogeology	7	Benefit
Soil Types	7	Cost

From the data above will be made one by one comparison for each criterion so that the data obtained as shown in table 2.

Table 2. Parameters and values data

Criteria	C1	C2	C3	C4	C5	C6
C1	1	1.4	0.6	1	1.4	1.4
C2	0,71	1	0,43	0,71	1	1
C3	1,67	2,33	1	1,67	2,33	2,33
C4	1	1.4	0.6	1	1.4	1.4
C5	0,71	1	0,43	0,71	1	1
C6	0,72	1	0,43	0,71	1	1
Jumlah	5,81	8,13	3,49	5,81	8,13	8,13

Explanation:

- C1: Slope
- C2: Land Use
- C3: Geology
- C4: Rainfall
- C5: Hydrogeology
- C6: Soil Types

3.2 Normalization of Criteria Weights

The next stage is the weighted criteria that have been compared normalized by dividing by the number of values in one row. Following is the acquisition of normalization values shown in table 3.

Table 3. Parameter Weight Table

Criteria	C1	C2	C3	C4	C5	C6	Total
C1	0.1721	0.1721	0.1721	0.1721	0.1721	0.1721	1,0328
C2	0.123	0.123	0.123	0.123	0.123	0.123	0,7377
C3	0.2869	0.2869	0.2869	0.2869	0.2869	0.2869	1,7213
C4	0.1721	0.1721	0.1721	0.1721	0.1721	0.1721	1,0328
C5	0.1230	0.1230	0.1230	0.1230	0.1230	0.1230	0,7377
C6	0.1230	0.123	0.123	0.123	0.123	0.123	0,7377

3.3 Determination of Priority Weight Value Criteria

At this stage the processing has been carried out using the formula weight criteria or total priority value, namely:

$$TPV = \frac{\sum w_{ij}}{n}$$

Explanation:

- TPV : Priority weights criteria value
- $\sum w_{ij}$: Total normalization sum of weights criteria
- n : Number of criteria

Samples of processing the criteria weights from the slope parameters can be obtained with the formula for priority weights criteria, namely:

$$TPV = \frac{1.0328}{6} = 0.1721$$

Likewise with other criteria will be done the same way with the formula of the priority value of criteria weights. The results of data processing the priority value of criteria weights can be shown in table 4.

Table 4. Table of Relative Weights

Parameter	Relative Weights
Slope (C1)	0.1721
Land Use (C2)	0.123
Geology (C3)	0.2868
Rainfall (C4)	0.1721
Hidrogeology (C5)	0.123
Soil Types (C6)	0.123

In the Topsis method, a calculation that takes the tpv value from the results of the previous method is AHP to obtain the final value from each of its districts.

3.4 Determination of Parameters and Values

First, the required criteria or parameter data and alternative data and their values are determined from the field, namely the Geodetic Department, in this case in the form of subdistrict data in Klaten Regency. These data are shown in table 5.

Table 5. Parameter and Values

Area	Criteria					
	C1	C2	C3	C4	C5	C6
Pedan	0	1	0	1	1	0
Karangdowo	0	1	4	1	1	0
Karanganom	0	1	0	0	0	0
Jatinom	1	1	0	0	0	0
Ngawen	0	1	0	0	0	0

Juwiring	0	1	2	2	1	0
Manisrenggo	1	1	0	1	0	1
Kalikotes	0	1	3	1	0	0
Ceper	0	1	0	1	0	0
Trucuk	1	3	0	1	0	0
Prambanan	1	3	0	1	0	1
Jogonalan	0	1	0	1	0	1
Bayat	2	3	1	1	2	1
Cawas	1	1	0	1	2	1
Delanggu	0	1	0	2	0	0
Kemalang	2	0	0	1	1	1
Tulung	1	1	0	0	0	0
Polanharjo	0	1	0	2	0	0
Wonosari	0	1	2	2	0	0
Karangnongko	1	1	0	1	0	0
Gantiwarno	1	1	2	1	2	1
Klaten Utara	0	3	0	0	0	0
Klaten Tengah	0	3	3	0	0	0
Klaten Selatan	0	4	0	0	0	0
Kebonarum	0	1	0	1	0	0
Wedi	2	1	0	1	2	1

Explanation :

- C1: Slope
- C2: Land Use
- C3: Geology
- C4: Rainfall
- C5: Hydrogeology
- C6: Soil Types

3.5 Determination The Value Divisor

The next step is to determine the value of the divisor by using the following formula:

$$y = \sqrt{\sum_{j=1}^m x_{ij}^2}$$

Explanation :

- y : Divider Value
- x_{ij} : i-alternative performance rating for the j-criterion

Samples determining the value of the divider from the slope parameter can be obtained by the formula of the divider value :

$$y = \sqrt{\frac{0^2 + 0^2 + 0^2 + 1^2 + 0^2 + 0^2 + 1^2 + 0^2 + 0^2 + 1^2 + 1^2 + 0^2 + 2^2}{1^2 + 0^2 + 2^2 + 1^2 + 0^2 + 0^2 + 1^2 + 1^2 + 0^2 + 0^2 + 0^2 + 0^2 + 2^2}}$$

$$= 4.4721$$

Likewise with other criteria will be done in the same way with the divisor value formula. The results of processing the divider value data can be shown in table 6.

Table 6. Divider Value Table

Parameter	Relative Weight
Slope (C1)	4.4721
Land Use (C2)	8.9442
Geology (C3)	6.8556
Rainfall (C4)	5.5677
Hidrogeology (C5)	4.5825
Soil Types (C6)	2.6457

3.6 Determination The Normalization Value

At this stage the processing has been carried out using the normalization formula

$$r_{ij} = \frac{x_{ij}}{y}$$

Explanation :

- r_{ij} : Normalized Element Value
- x_{ij} : Alternative performance rating i to the j criterion
- y : Divider Value

Normalization processing samples from Pedan Subdistrict slope parameters can be obtained with the normalization formula :

$$r_{ij} = \frac{0}{4.4721} = 0$$

Likewise with other parameters and sub-districts carried out with the same normalization formula. Normalization data processing results can be shown in table 7.

Table 7. Normalization Table

Subdistrict	Criteria					
	C1	C2	C3	C4	C5	C6
Pedan	0	0.1118	0	0.1796	0.2182	0
Karangdowo	0	0.1118	0.5835	0.1796	0.2182	0
Karanganom	0	0.1118	0	0	0	0
Jatinom	0.2236	0.1118	0	0	0	0
Ngawen	0	0.1118	0	0	0	0
Juwiring	0	0.1118	0.2917	0.3592	0.2182	0
Manisrenggo	0.2236	0.1118	0	0.1796	0	0.3536
Kalikotes	0	0.1118	0.4376	0.1796	0	0
Ceper	0	0.1118	0	0.1796	0	0
Trucuk	0.2236	0.3354	0	0.1796	0.2182	0
Prambanan	0.2236	0.3354	0	0.1796	0	0.3536
Jogonalan	0	0.1118	0	0.1796	0	0.3536

Bayat	0.4472	0.3354	0.1459	0.1796	0.4364	0.3536
Cawas	0.2236	0.1118	0	0.1796	0.4364	0.3536
Delanggu	0	0.1118	0	0.3592	0	0
Kemalang	0.4472	0	0	0.1796	0.2182	0.3536
Tulung	0.2236	0.1118	0	0	0	0
Polanharjo	0	0.1118	0	0.3592	0	0
Wonosari	0	0.1118	0.2917	0.3592	0	0
Karangnongko	0.2236	0.1118	0	0.1796	0	0
Gantiwarno	0.2236	0.1118	0.2917	0.1796	0.4364	0.3536
Klaten Utara	0	0.3354	0	0	0	0
Klaten Tengah	0	0.3354	0.4376	0	0	0
Klaten Selatan	0	0.4472	0	0	0	0
Kebonarum	0	0.1118	0	0.1796	0	0
Wedi	0.4472	0.1118	0	0.1796	0.4364	0.3536

3.7 Determination of Weighted Normalization

At this stage a multiplication is made between the normalized value and the priority value of the criteria weights. Samples of normalization values & priority values for criteria weights are shown as follows:

Pedan Subdistrict with the slope criteria has a normalization value of 0 based on table 7. With the priority value of the slope criteria weight is 0.1721 based on table 4. Then, the weighted normalization value is obtained in the ampelgading area with the slope parameter is 0. The results of weighted normalization data processing are shown in table 8.

Table 8. Weighted Normalization Table

Subdistrict	Criteria					
	C1	C2	C3	C4	C5	C6
Pedan	0	0.0137	0	0.0309	0.0268	0
Karangdowo	0	0.0137	0.1674	0.0309	0.0268	0
Karanganom	0	0.0137	0	0	0	0
Jatinom	0.0385	0.0137	0	0	0	0
Ngawen	0	0.0137	0	0	0	0
Juwiring	0	0.0137	0.2917	0.0618	0.0268	0
Manisrenggo	0.0385	0.0137	0	0.0309	0	0.0435
Kalikotes	0	0.0137	0.4376	0.0309	0	0
Ceper	0	0.0137	0	0.0309	0	0
Trucuk	0.0385	0.0412	0	0.0309	0.0268	0
Prambanan	0.0385	0.0412	0	0.0309	0	0.0435
Jogonalan	0	0.0137	0	0.0309	0	0.0435
Bayat	0.077	0.0412	0.1459	0.0309	0.0537	0.0435
Cawas	0.0385	0.0137	0	0.0309	0.0537	0.0435
Delanggu	0	0.0137	0	0.3592	0	0

Kemalang	0.077	0	0	0.1796	0.0268	0.0435
Tulung	0.0385	0.0137	0	0	0	0
Polanharjo	0	0.0137	0	0.0618	0	0
Wonosari	0	0.0137	0.0837	0.0618	0	0
Karangnongko	0.0385	0.0137	0	0.0309	0	0
Gantiwarno	0.0385	0.0137	0.0837	0.0309	0.0537	0.0435
Klaten Utara	0	0.0412	0	0	0	0
Klaten Tengah	0	0.0412	0.1255	0	0	0
Klaten Selatan	0	0.055	0	0	0	0
Kebonarum	0	0.0137	0	0.0309	0	0
Wedi	0.077	0.0137	0	0.0309	0.0537	0.0435

3.8 Determination of The Value of the Ideal Solution

There are two types of ideal solution values, namely the positive ideal solution (+) and the negative ideal solution (-), performed data processing using the ideal solution formula, namely:

$$y_j^+ = \begin{cases} \max_{iyij,if j=benefit} \\ \min_{iyij,if j=cost} \end{cases} \quad (4)$$

$$y_j^- = \begin{cases} \max_{iyij,if j=cost} \\ \min_{iyij,if j=benefit} \end{cases} \quad (5)$$

Explanation:

- y_j^+ : Value of Positive Ideal Solution Elements
- y_j^- : Value of Negative Ideal Solution Elements

Sample processing the value of an ideal solution with the criteria for slope which is a benefit by looking at table 8 and table 1 obtained by the evaluation factor formula, namely:

$$y_j^+ = 0,118$$

$$y_j^- = 0$$

Likewise with other parameters and sub-districts carried out with the same normalization formula. Normalization data processing results can be shown in table 9.

Table 9. Weighted Normalization Table

Criteria Value	C1	C2	C3	C4	C5	C6
y^+	0.0769	0.0549	0.1673	0	0.0536	0
y^-	0	0	0	0.0618	0	0.0434

3.9 Determination of The Value of the Ideal Solution

At this stage there are two types of alternative value distances, namely the distance of the positive ideal solution value (d^+) and the distance of the negative ideal solution value (d^-), performed data processing using the alternative value distance formula :

$$d_i^+ = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^+)^2}$$

$$d_i^- = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^-)^2}$$

Explanation :

- v_j^+ : Value of Positive Ideal Solution Elements
- v_j^- : Value of Negative Ideal Solution Elements
- d_i^+ : Positive Alternative Distance Value
- d_i^- : Negative Alternative Distance Value

Likewise with other sub-districts carried out with the same alternative value distance formula. The results of distance data processing of alternative values can be shown in table 10.

Table 10. Table of Distance Value Alternative Values

Sub-district	D ⁺	D ⁻
Pedan	0.19318437015576984	0.0612715705063838
Karangdowo	0.09644744253328615	0.17824785287231013
Karanganom	0.196275266275092	0.0768224455477994
Jatinom	0.18460663675661443	0.08592522764319277
Ngawen	0.196275266275092	0.0768224455477994
Juwiring	0.13847009591311363	0.09900984709824051
Manisrenggo	0.19215879320796622	0.05124642780275117
Kalikotes	0.11494693400276913	0.1370931411714353
Ceper	0.19869513986652404	0.05508495960138976
Trucuk	0.17709923952926668	0.08214226909317697
Prambanan	0.18818424852594512	0.06432640807949584
Jogonalan	0.20339462043995069	0.03383400296968558
Bayat	0.1370931411714353	0.11494693400276912
Cawas	0.1845144750284211	0.07419977543544633
Delanggu	0.2057840955278989	0.045591384263558556
Kemalang	0.18602880577907768	0.08718633755130954
Tulung	0.18460663675661443	0.08592522764319277
Polanharjo	0.2057840955278989	0.045591384263558556
Wonosari	0.14606000546447664	0.09530528445151898
Karangnongko	0.1871774259621279	0.06719977217131497
Gantiwarno	0.11415788504987891	0.1118486906494133
Klaten Utara	0.19238578361586656	0.08610097882028894

Klaten Tengah	0.10365967763576363	0.15222862784567232
Klaten Selatan	0.19189405523819028	0.09346714752224805
Kebonarum	0.19869513986652404	0.05508495960138976
Wedi	0.1804553542830579	0.09974956887846859

3.10 Determination of The Rank

At this stage it is the final stage of the TOPSIS method by making calculations with the formula:

$$c_i = \frac{d_i^-}{d_j^- + d_i^+}$$

Explanation :

- c_i : End Value
- d_i^+ : Positive Alternative Distance Value
- d_j^- : Negative Alternative Distance Value

Samples of ranking processing with alternative Pedan Subdistricts by looking at table 11 obtained with the final result formula, namely:

$$c_i = \frac{0.0612715705063838}{0.0612715705063838 + 0.19318437015576984} = 0.2408$$

The final results of the Topsis method are shown in table 11.

Table 11. Rank Table

Peringkat	Sub-district	Hasil
1	Karangdowo	0.6489
2	Klaten Tengah	0.5949
3	Kalikotes	0.5439
4	Gantiwarno	0.4949
5	Bayat	0.4561
6	Juwiring	0.4169
7	Wonosari	0.3949
8	Wedi	0.356
9	Klaten Selatan	0.3275
10	Kemalang	0.3191
11	Jatinom	0.3176
12	Tulung	0.3176
13	Trucuk	0.3169
14	Klaten Utara	0.3092
15	Cawas	0.2868
16	Ngawen	0.2813
17	Karanganom	0.2813
18	Karangnongko	0.2642

19	Prambanan	0.2547
20	Pedan	0.2408
21	Ceper	0.2171
22	Kebonarum	0.2171
23	Manisrenggo	0.2105
24	Delanggu	0.1814
25	Polanharjo	0.1814
26	Jogonalan	0.1426

A Web-based Decision Support System created to determine the critical land area in Klaten Regency. The information system created has an alternative menu and criteria that determine the potential of critical land in Klaten Regency, making it easier for users to obtain information. The results of ranking the decision support system using the web-based AHP-TOPSIS method are shown in Figure 1.

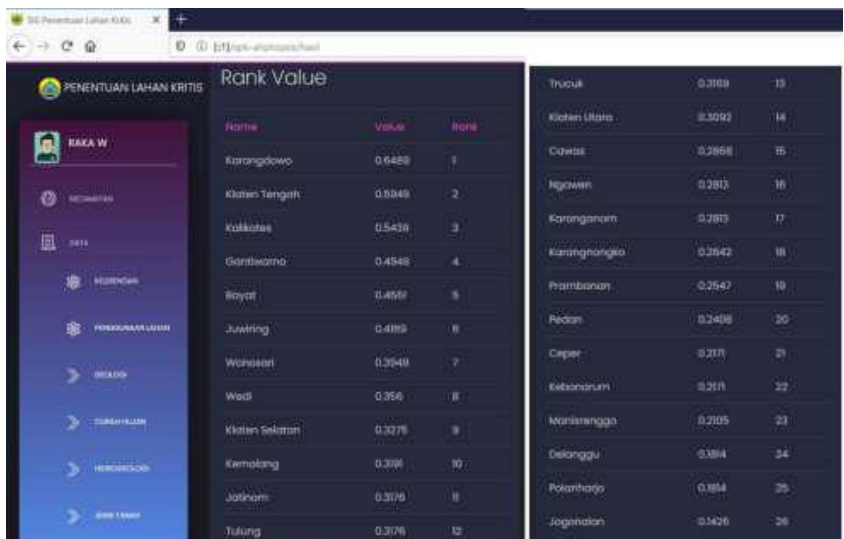


Fig. 1. A Web-based Decision Support System for Critical Land.

4. Result

The implementation of Analytic Hierarchy Process and Topsis methods for this Critical Land Decision Support Support System was built using web-based. Alternative data and criteria data can be accessed on the sub-district and data pages. After the data is ready to be processed, the system will dynamically perform the processing using the AHP and TOPSIS methods and the results will be displayed on the system at each step. The use of the combination of AHP and TOPSIS is because the AHP method is less effective when used in cases that have a large number of criteria and alternatives, in this case there are quite a number of alternatives namely 26 alternatives, so combined with the TOPSIS method used to determine the priority level of alternatives to be more effective and efficient in the calculation process. The system that has been made can recommend the Regional Development Planning Agency of Klaten (Bappeda) in determining the priority of critical land in the Klaten Regency. The Supporting System for Critical Land Determination

Decisions in Klaten District using the Analytic Hierarchy Process and TOPSIS methods built on a web-based result shows that the Karangdowo District area has the highest final yield value of 0.6489 and Jogonalan District with the lowest value of 0.1426.

Acknowledgment

The authors are also grateful to the Research and Community Service Institute of Diponegoro University (LPPM-UNDIP) for funding the Research and Development Research (RPP) and Regional Development Planning Agency of Klaten (Bappeda) and Klaten Public Works and Spatial Planning Office (DPUPR).

References

- [1] Y. Shao, Q. Jiang, C. Wang, M. Wang, L. Xiao, and Y. Qi, —Analysis of critical land degradation and development processes and their driving mechanism in the Heihe River Basin,|| *Sci. Total Environ.*, vol. **716**, p. 137082, 2020, doi: 10.1016/j.scitotenv.(2020).137082.
- [2] D. Patrman, A. Splichalova, D. Rehak, and V. Onderkova, —Factors influencing the performance of critical land transport infrastructure elements,|| *Transp. Res. Procedia*, vol. **40**, pp. 1518–1524, (2019), doi: 10.1016/j.trpro.2019.07.210.
- [3] M. Rajasekhar, G. Sudarsana Raju, Y. Sreenivasulu, and R. Siddi Raju, —Delineation of groundwater potential zones in semi-arid region of Jilledubanderu river basin, Anantapur District, Andhra Pradesh, India using fuzzy logic, AHP and integrated fuzzy-AHP approaches,|| *HydroResearch*, vol. **2**, pp. 97–108, (2019), doi: 10.1016/j.hydres.2019.11.006.
- [4] A. E. Wolnowska and W. Konicki, —Multi-criterial analysis of oversize cargo transport through the city, using the AHP method,|| *Transp. Res. Procedia*, vol. **39**, no. 2018, pp. 614–623, (2019), doi: 10.1016/j.trpro.2019.06.063.
- [5] E. Lima, E. Gorski, E. F. R. Loures, E. A. Portela Santos, and F. Deschamps, —Applying machine learning to AHP multicriteria decision making method to assets prioritization in the context of industrial maintenance 4.0,|| *IFAC-PapersOnLine*, vol. **52**, no. 13, pp. 2152–2157, (2019), doi: 10.1016/j.ifacol.2019.11.524.
- [6] F. Moussaoui, M. Cherrared, M. A. Kacimi, and R. Belarbi, —A genetic algorithm to optimize consistency ratio in AHP method for energy performance assessment of residential buildings—Application of top-down and bottom-up approaches in Algerian case study,|| *Sustain. Cities Soc.*, vol. **42**, pp. 622–636, (2018), doi: 10.1016/j.scs.2017.08.008.
- [7] A. Calabrese, R. Costa, N. Levialdi, and T. Menichini, —Integrating sustainability into strategic decision-making: A fuzzy AHP method for the selection of relevant sustainability issues,|| *Technol. Forecast. Soc. Change*, vol. **139**, no. March, pp. 155–168, (2019), doi: 10.1016/j.techfore.2018.11.005.
- [8] C. Ulloa, J. M. Nuñez, C. Lin, and G. Rey, —AHP-based design method of a lightweight, portable and flexible air-based PV-T module for UAV shelter hangars,|| *Renew. Energy*, vol. **123**, pp. 767–780, (2018), doi: 10.1016/j.renene.2018.02.099.
- [9] M. Khalili, K. Jadidi, M. Karakouzian, and S. Amirkhanian, —Rheological properties of modified crumb rubber asphalt binder and selecting the best modified binder using AHP method,|| *Case Stud. Constr. Mater.*, vol. **11**, p. e00276, (2019), doi: 10.1016/j.cscm.2019.e00276.

- [10] B. Tashayo, A. Honarbakhsh, M. Akbari, and M. Eftekhari, —Land suitability assessment for maize farming using a GIS-AHP method for a semi- arid region, Iran,|| *J. Saudi Soc. Agric. Sci.*, no. xxxx, (2020), doi: 10.1016/j.jssas.2020.03.003.
- [11] M. Kim, Y. C. Jang, and S. Lee, —Application of Delphi-AHP methods to select the priorities of WEEE for recycling in a waste management decision-making tool,|| *J. Environ. Manage.*, vol. **128**, pp. 941–948, (2013),doi:10.1016/j.jenvman.2013.06.049.
- [12] C. Ren, Z. Li, and H. Zhang, —Integrated multi-objective stochastic fuzzy programming and AHP method for agricultural water and land optimization allocation under multiple uncertainties,|| *J. Clean. Prod.*, vol. **210**, pp. 12–24, (2019), doi: 10.1016/j.jclepro.2018.10.348.
- [13] I. Aşçhilean, G. Badea, I. Giurca, G. S. Naghiu, and F. G. Iloaie, —Choosing the Optimal Technology to Rehabilitate the Pipes in Water Distribution Systems Using the AHP Method,|| *Energy Procedia*, vol. **112**, no. October 2016, pp. 19–26, (2017), doi: 10.1016/j.egypro.2017.03.1109.
- [14] P. Chen, —Effects of normalization on the entropy-based TOPSIS method,|| *Expert Syst. Appl.*, vol. **136**, pp. 33–41, (2019), doi: 10.1016/j.eswa.2019.06.035.
- [15] X. Ye, Y. Kang, Z. Yan, B. Chen, and K. Zhong, —Optimization study of return vent height for an impinging jet ventilation system with exhaust/return-split configuration by TOPSIS method,|| *Build. Environ.*, vol. **177**, no. April, p. 106858, (2020), doi: 10.1016/j.buildenv.2020.106858.
- [16] R. F. de F. Aires and L. Ferreira, —A new approach to avoid rank reversal cases in the TOPSIS method,|| *Comput. Ind. Eng.*, vol. **132**, no. April, pp. 84–97, (2019), doi: 10.1016/j.cie.2019.04.023.
- [17] S. Yousefzadeh, K. Yaghmaeian, A. H. Mahvi, S. Nasserri, N. Alavi, and R. Nabizadeh, —Comparative analysis of hydrometallurgical methods for the recovery of Cu from circuit boards: Optimization using response surface and selection of the best technique by two-step fuzzy AHP-TOPSIS method,|| *J. Clean. Prod.*, vol. **249**, p. 119401, (2020), doi: 10.1016/j.jclepro.2019.119401.