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Mapping Residential Land Suitability Using a WEB-GIS-Based Multi-Criteria Spatial Analysis Approach: Integration of AHP and WPM Methods

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Abstract

Along with the increase in population and the acceleration of economic growth, the urgent need for additional property that can serve as a place for various community activities also increases. It is typical for big cities that are the epicenter of urbanization to experience a sharp spike in land demand. One area that has excellent accessibility is Sidarjo Regency, which is comparable to Surabaya City in this regard. This research aims to use Web-GIS to conduct spatial data analysis to identify the most suitable land functions for use in residential areas. Analytic Hierarchy Process (AHP) and Weighted Product Model (WPM) are used in this research for spatial data modeling based on multi-criteria decision-making (MCDM). Parameters were based on distance to the city center, distance to the market, distance to the hospital, distance to public transport, slope, soil type, and rainfall intensity. The results of spatial data modeling categorize the suitability of new settlement land into the categories of uninhabitable and habitable land. The K value of 0.27 is the outcome of a comparison test between the two MCDM approaches using Cohen's Kappa coefficient. The test indicates that the K value falls into the category of having a fair strength of agreement between the two methods that came into play.

Keywords: *spatial analysis; MCDM; WPM method; AHP method; cohen's kappa.*

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1. Introduction

Along with the increasing population and economic growth, the need for land for community activities is growing rapidly. Large cities such as Surabaya, one of the centers of urbanization, are also experiencing a sharp increase in land demand at an alarming rate. While the demand for land in Surabaya continues to increase, the amount of land available in the city is starting to deplete, which has caused residents to start moving to Sidarjo Regency, which is one of the areas that has good accessibility and accessibility [1]. Comparable to Surabaya City. As Sidoarjo is a vital area with complete services and utilities, it has become a major residential destination of choice for people living in Surabaya. The northern part of Sidoarjo, particularly Waru, Sedati, Buduran, Candi, and Sidoarjo sub-districts, has seen the most significant increase in the rate of house construction (both village and developer) in recent years. According to the Sidoarjo District Public Works and Spatial Planning Office, often known as the Public Works and Spatial Planning Office, housing land increased by 28% between 2010 and 2015, and this trend is expected to continue to increase [1].

Manually monitoring residential land development will require time, effort, and money. Therefore, it is difficult for many real estate developers and the Sidoarjo District Public Works and Spatial Planning Office to find suitable properties for residential construction. In 2016, the total population in Sidoarjo was 2,223,002 people, an increase of 49.93% compared to 2015. According to

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those who came and moved in 2016, population growth increased by 9.59% compared to 2015. The number of residents coming to Sidoarjo district consistently hovers around 2000-3000 people. Most of these outsiders are residents who live in the lodge but work in Surabaya. This increase impacts floating capacity and the settlement environment because the smaller and poorer the ability to finance the maintenance of housing and settlement infrastructure, the worse the environmental conditions, causing the formation of slums [2].

Previous research used the Fuzzy Mamdani method to analyze the suitability of residential land based on data parameters of land height, slope, length of inundation, distance of main roads, and distance to hospitals, terminals, and markets [3]. The result of the method is to get a land suitability value smaller than 40 in the unsuitable category. The subsequent research used the MCE technique to analyze the suitability of residential land based on security parameters, distance to roads, university, city center, and topography [4]. Researcher [5] uses a quantitative descriptive method, using a spatial analysis approach with the help of GIS to analyze the suitability of residential land based on the parameters of land capability unit analysis, including morphology, workability, slope stability, foundation stability, water supply capacity, drainage, waste treatment, anti-erosion, and natural disaster. The results of land that follows the plan for residential land use with land suitability analysis are only 41.64%, and those that are not suitable or have a deviation in residential land use are 58.32% [5]. The study [6] used scoring and overlay methods to evaluate the suitability of settlement land based on slope, rainfall, and soil type factors, as well as a map indicating areas prone to natural disasters. The method results show the suitability of settlement land, which is very suitable at 14.45%, 24.27%, less suitable at 54%, and unsuitable at 7.28% [6]. The study [7] will assess the suitability of settlement land based on the criteria of slope, rock type, parent soil type, rainfall, existing land use, and road network. This analysis will be conducted using descriptive methods and a quantitative approach. The result of the technique used is that the settlement area is 42% very high, 28% high, and 12% medium [7]. The research [8] uses the spatial analysis method of scoring and overlaying it with Geographic Information Systems (GIS) to analyze the suitability of residential land based on topographic parameters, slope morphology, and soil type. The results of the method used for the suitability of residential land use against the direction of land suitability are suitable criteria (A) of 2.07%, suitable criteria (B) of 39.29%, unsuitable criteria (A) of 0.04%, unsuitable criteria (B) of 58.60% [8].

The following research uses the multi-criteria Evaluation and AHP methods to analyze the suitability of residential land based on the parameters of distance to road, distance to education, distance to health, distance to station, distance to terminal, and land slope. The results of the method show that the land area of (54.21%) is very suitable to be used as an urban area of Sidoarjo Regency. Only (2.08%) of the land area in Sidoarjo Regency is unsuitable [9]. The literature study results show that various methods have been used for spatial analysis of housing land suitability mapping. However, no research has specifically conducted a comparative study by integrating the Analytical Hierarchy Process (AHP) and Weighted Product Model (WPM) methods based on multi-criteria decision-making (MCDM) [10]–[12]based on the parameters of distance to city center, market, hospital, and public transportation, as well as slope, soil type, and rainfall. The comparative study aims to improve the accuracy and efficiency of the prediction results of these methods and determine which method provides the most accurate and reliable results. This study proposes using the AHP and WPM methods because both methods are popular in multi-criteria-based decision analysis. The advantages and disadvantages of the two methods are highly dependent on different implementation scopes, as each relies heavily on expert opinion in multi-criteria weighting, which will lead to unobjective judgment in influencing the model's performance.

This research analyzes the function of suitable land as a residential area using Web-based GIS technology (Web-GIS). The application of Web-GIS in mapping suitable land for new housing development will simplify and speed up the data analysis process. GIS technology is a relatively new technology rapidly developing into a necessary instrument for storing, manipulating, evaluating, and displaying natural situations with the help of attribute and spatial data [13]. This research will use AHP and WPM methods to analyze suitable land functions as residential areas by showing two conditions, namely suitable and unsuitable, based on data on city center distance, market distance, hospital distance, public transportation distance, slope, soil type, and rainfall. This research aims to determine whether or not a certain area is suitable for residential use.

2. Research Methods

Research stages for the suitability of new housing land based on the flow in Figure 1.

The first step is to describe the needs of the spatial dataset layer to determine the classification of suitable or unsuitable land suitability for new housing construction based on seven parameters. Furthermore, the calculation process is carried out using the AHP and WPM method approaches and the Guttman Scale to determine the value of the level of importance of the appropriate or inappropriate class category.

2.1 Spatial Dataset Requirements

The spatial dataset requirement in GIS consists of two components: spatial data and attribute data [14]. Spatial datasets classify the elements that influence selecting suitable housing land. Table 1 is a collection of spatial data used as spatial analysis parameters in this study.

Each value in the spatial dataset has an associated range value used to establish the maximum permissible level of effect on the feasibility of new land [Source: 2010 Central Bureau of Statistics Director Regulation No. 37]. The sample data used in this study refers to the Sidoarjo District Public Works and Spatial Planning Office. ArcMap software is used as a tool to process spatial data and attribute data.

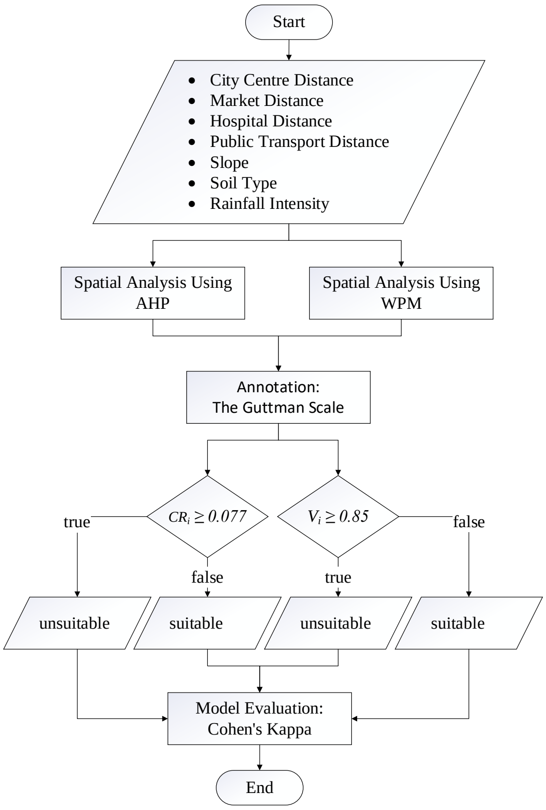


Figure 1. Research Stages for Spatial Analysis

Table 1. Spatial parameters of residential land suitability dataset

Spatial Datasets	Range	Description
City Centre Distance	≤ 5 Km	Near
	> 5 Km	Medium
Market Distance	≤ 5 Km	Near
	> 5 Km	Medium
Hospital Distance	≤ 5 Km	Near
	> 5 Km	Medium
Public Transport Distance	≤ 5 Km	Near
	> 5 Km	Medium
Slope	0 ≤ 8	Flat
	8 ≤ 15	Ramps
	15 ≤ 25	Wave
	25 ≤ 40	Steep
	40 ≤ 41	Very steep
Soil Type	5	Large
	4	Somewhat
	3	Large
	2	Medium
	1	Somewhat
		Small
		Small
Rainfall Intensity	>= 5500	Large
	4500-5500	Somewhat
	3500-4500	Large
	2500-3500	Medium
	<= 2500	Somewhat
		Small
		Small

This research uses various characteristics or parameters to evaluate land suitability for residential use. These parameters are derived from data such as distance to city center, distance to market, distance to hospital, distance to public transport, slope, soil type, and amount of rainfall. These parameters are used to evaluate various aspects of the land, such as its proximity to important locations, accessibility to public transportation, suitability of the land for construction, and its exposure to natural disasters such as flooding. The research aims to identify land with the best residential-use characteristics. It is important to mention that these characteristics are based on the research objectives and data availability. Some other characteristics may be added or removed depending on the specific context.

2.2 Weight Product Model (WPM)

The stages using the WPM method [15]–[17] are:

Step 1: Calculating the weight of the criteria W_j. The weight calculation formula to obtain the total weight $\sum wj = 1$ using Formula 1.

$$W_j = \frac{w_j}{\sum_j^n w_j} \tag{1}$$

Step 2: Calculating the S_i vector using Formula 2. Where the *S* variable is an alternative preference represented as a vector, the *X* variable is the criterion value, the *W* variable is the weight of criteria and sub-criteria, *i* variable is a variable that represents an alternative, the *j* variable represents a criterion, and variable *n* indicates the number of criteria.

$$S_i = \prod_j^n = 1\, X_{ij}\, W^j \quad ;\ i = 1, 2, n \tag{2}$$

Step 3: Calculate the value of vector V_i utilizing the calculation results of each Vector S_i divided by the sum of the calculation results of all vectors S_i. The vector calculation can be used in Formula 3.

$$V_i = \frac{S_i}{S_1 + S_2 + S_3 + S_n}\ ;\ i=1, 2, n \tag{3}$$

The vector V_i calculation results as the basis for decision-making. The largest V_i variable value is the best alternative choice.

2.3. Analytical Hierarchy Process *(AHP)*

The problem-solving stage in each case in the AHP method is first to complete the standard weight matrix, followed by the alternatives [18]. This method is unique compared to other methods because of the standard weights. W_i They are determined based on the evaluation results of the standard weight matrix, which are not predetermined by stakeholders compared to other methods. The AHP approach consists of questions, criteria, and alternatives.

The following is a problem-solving algorithm using the AHP method [19], namely: *Step 1*: Determine the nature of the problem and the action required; *Step 2*: Define the framework, criteria, alternatives, and overarching criteria that will form the basis for finding a solution to the problem; *Step 3*: Based on the relevance values presented in Table 2 [20], determine the importance of each criterion and then develop a pairwise comparison matrix for the criteria. The next step is to add the values in column *j*, and repeat the process for each column using Formula 4, to determine the total number of values. Where the value of a matrix is denoted by a_{ij}, and is located in the *i-th* row of the *j-th* column.

$$\sum_{i=1}^{n} a_{ij}, \qquad j = 1,2,3,n \tag{4}$$

Table 2. The Pairwise Comparison Matrix Importance Level

Degree of Importance	Descriptions
1	Equally important
3	Somewhat Very Important (1 Level more critical than other criteria)
5	More critical (2 Levels more important than other criteria)
7	Significantly more critical (3 Levels more important than other criteria)
9	More critical (4 Levels more critical than other criteria)
2,4,6,8	The value lies in the middle of two other values considered neighboring, which is given when there are two different compromises to be made between two different options.

Step 4: Calculate the new priority weight for the replacement by dividing each value in the *j-th* column by the column number value. This will result in a value of one in the new column. The calculation can use Formula 5, where the matrix values in the *i-th* row and *j-th* column are denoted by a_{ij}.

$$\sum_{1}^{n} \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} = 1, \; j = 1,2,3,n \tag{5}$$

After summing up the values in the *i-th* row, divide the total by the number of criteria using Formulas 6 and 7. Where the variable W_i represents the priority weight of the *i-th* criterion, the variable *n* states the total number of criteria, and the value of a matrix in the *i-th* row and *j-th* column is denoted by the variable a_{ij}.

$$\sum_{j=1}^{n} a_{ij}, \qquad i = 1,2,3,n \tag{6}$$

$$W_i = \frac{1}{n} \sum_{j=1}^{n} a_{ij}, \; j = 1,2,3,n \tag{7}$$

Step 5: Calculate all composite weight (CW) or global priority. CW values can be obtained using Formula 8 to exchange the alternative priority weights with the criterion priority weights. where a_{ij} is the value of the i-th row and j-th column of the matrix, W_j is the *j-th* criterion priority weight, and CW is the composite weight of the *i-th* alternative. The most important recommendation obtained from the CW has the highest value, the second most important recommendation is number two, and so on, until the last recommendation has the smallest value.

$$\sum_{j}^{n} (A_{1j} . W_j) = (a_{i1} . w_1) + (a_{i2} . w_2) + (a_{i3} . w_3) \tag{8}$$

$$\begin{array}{c} \\ Alter_1 \\ Alter_2 \\ Alter_3 \\ Alter_4 \end{array} \begin{array}{c} \begin{array}{ccc} Kriteria_1 & Kriteria_2 & Kriteria_3 \end{array} \\ \begin{bmatrix} a_1 & a_2 & a_n \\ a_1 & a_2 & a_n \\ a_1 & a_2 & a_n \\ a_1 & a_2 & a_n \end{bmatrix} \end{array} \; x \begin{array}{c} W_j \\ \begin{bmatrix} W_1 \\ W_2 \\ W_3 \\ W_N \end{bmatrix} \end{array} = \begin{array}{c} CW \\ \begin{bmatrix} CW \\ CW \\ CW \\ CW \end{bmatrix} \end{array}$$

Step 6: Perform a consistency check by multiplying the pairwise comparison matrix by the priority weights, then dividing the multiplication result by each relevant priority weight to get the lambda value or eigenvalue. The calculation can use Formula 9. Where the variable λ_i represents the eigenvalue for the *i-th* criterion, the variable W_i represents the priority weight for the *i-th* criterion, the variable W_j represents the priority weight for the *j-th* criterion, and the variable x_{ij} represents the value in the comparison matrix.

$$\lambda_i = \frac{\sum_{j=1}^{n} (x_{ij} . W_j)}{W_i}, i = 1,2,3,n \tag{9}$$

Step 7: Determine the largest lambda by finding the average of all lambda values and entering the number into Formula 10. Where *n* variable refers to the total number of criteria and λ_{maks} is the average of all eigen values.

$$\lambda_{maks} = \frac{\lambda_1 + \lambda_2 + \cdots + \lambda_n}{n} \tag{10}$$

Step 8: Determine the Consistency Index (CI) using Formula 11. Where CI is the consistency index, the *n* variable indicates the number of criteria or options, and λ_{maks} variable indicates the average eigenvalue.

$$CI = \frac{\lambda_{maks} - n}{n-1} \tag{11}$$

Step 9: Determine the Consistency Ratio (CR) [20] using Formula 12 as shown in Table 3, where CR is the consistent rate, CI is the consistency index, and IR is the randomness index.

$$CR = \frac{CI}{IR} \tag{12}$$

Table 3. Consistency Ratio AHP

n- Criteria	IR_n	n-Criteria	IR_n
1	0	16	1.60
2	0	17	1.61
3	0.58	18	1.62
4	0.90	19	1.63
5	1.12	20	1.63
6	1.24	21	1.64
7	1.32	22	1.65
8	1.41	23	1.65
9	1.45	24	1.66
10	1.49	25	1.66
11	1.51	26	1.67
12	1.48	27	1.67
13	1.56	28	1.67
14	1.57	29	1.68
15	1.59	30	1.68

2.4 The Guttman Scale

The Guttman scale provides a measurement basis for concluding qualitative data. It is also used to estimate categorical outcome values despite ambiguous intervention scores due to uncertainty[21], [22]. In these datasets that use scores or weights during analysis, scores are assigned based on an uncertainty factor for the class of variable described. This uncertainty factor can be determined using the Guttman scale [21], [22], based on Formula 13.

$$I = \frac{R}{K} \quad (13)$$

In this Equation, the *I* variable represents the interval score result, the *R* variable represents the maximum score minus the lowest score, and the *K* variable represents the number of classifications that may be used. The scale that will be used to calculate the grade criteria will be determined, and this will involve taking the highest score and subtracting it from the *I* variable.

Table 4. The Guttman Scale Determination

K Value Range	Strength of Agreement
< 20	Poor
0.21 – 0.40	Fair
0.41 – 0.60	Moderate
0.61 – 0.80	Good
0.81 – 1.00	Very Good

2.5 Model Validation Test

Cohen's Kappa was used for validation testing in this investigation. The degree of agreement in category classification for the same two variables can be measured using Cohen's Kappa [15]. This statistic can only be calculated if three raters evaluate one trial in each sample, two raters evaluate two trials in each sample, and one rater evaluates all three.

The Equation used to calculate the validation test results using Formula 14. The P_o variable represents the extent to which the ratings agree, and the P_e variable indicates the likelihood that the ratings are coincidental.

$$K = \frac{P_o - P_e}{1 - P_e} \quad (14)$$

3. Results and Discussions

The result of the spatial data modeling is to classify the land into two classes: mapping the suitability or unsuitability of settlement land. This categorization is based on evaluating land characteristics using the multi-criteria decision-making methodologies AHP and WPM. Land considered unsuitable for housing will have characteristics that would make it difficult or impossible to use for housing, such as high slopes or poor soil quality. Land that can be used for housing will have characteristics that make it suitable, such as proximity to important locations and good accessibility. It is important to note that this categorization is based on the objectives of the study and the criteria chosen. Different studies may have different criteria and, therefore, different results. In addition, researchers can use the results of this analysis to identify areas where land use planning or development efforts may be most effective and to make recommendations on how best to use land in the Sidoarjo district to meet growing housing demand.

3.1 Results

The experimental results will be tested in a village area, and the parameters used in these results correspond to the parameters in Table 1.

Figure 2 (a) shows the results of the Web-GIS-based spatial analysis for the new land suitability of Sidoarjo District using WPM method. Green criteria will result in suitable land; red is classified as unsuitable. From Figure 4, the results of the pie chart with the wpm method 89% suitable (*sesuai*) and 11% unsuitable (*tidak sesuai*) of 18 sub-districts Sidoarjo district among them sub-districts Balong Bendo, Buduran, Gedangan, Jabon, Krembung, Krian, Porong, Prambon, Sedati, Sukodono, Taman, Tanggulangin, Tarik, Tulangan, Waru, Wonoayu suitable and Candi, Sidoarjo unsuitable.

Figure 2 (b) pie chart results with AHP method 56% suitable (*sesuai*) and 44% unsuitable (*tidak sesuai*) of 18 sub-districts Sidoarjo district including sub-district Buduran, Candi, Gedangan, Porong, Sedati, Sidoarjo¸ Sukodono, Taman, Tanggulangin, Tulangan suitable and Balong Bendo, Jabon, Krembung, Krian, Prambon, Tarik, Waru, Wonoayu unsuitable.

Determine the initialized weights by providing input weights for the initial input to the hidden layer for each parameter based on the flow in Figure 1. Find the relative value of initial weights *W* for all alternative criteria. The initial weight data will be shown in Table 5.

Table 5. Criteria and Weight of WPM Method Parameters

Criteria	Initialization	Weight
Distance to the city center	P1	1
Distance to market	P2	1
Distance to hospital	P3	1
Distance to public transport	P4	1
Slope	P5	2
Rainfall intensity	P6	2
Soil type	P7	2

Spatial analysis for Residential Land Suitability using WPM method:

Step 1: Multiply 1 for *W* is profit, and multiply -1 for *W* is cost. Cost criteria for P1, P2, P3 and P4. Profit criteria for P5, P6, and P7 using Formula (1).

$$W_1 = \frac{1}{1+1+1+1+2+2+2} = \frac{1}{10} = 0{,}1 * (-1) = -0{,}1$$

Step 2: Find each alternative's normalized S preference value using Formula (2).

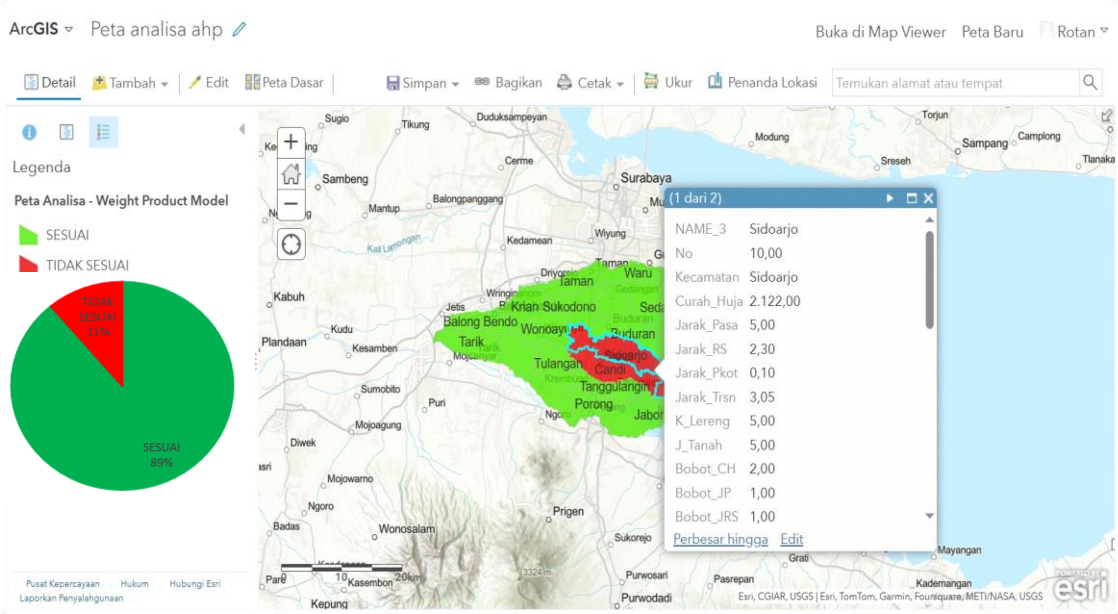
$$S_1 = (26^{-0.1})(7^{-0.1})(25^{-0.1})(24.5^{-0.1})(5^{0.2})\ (1400^{0.2})(5^{0.2}) = 2.54$$

Step 3: Find the value of *V* using Formula (3).

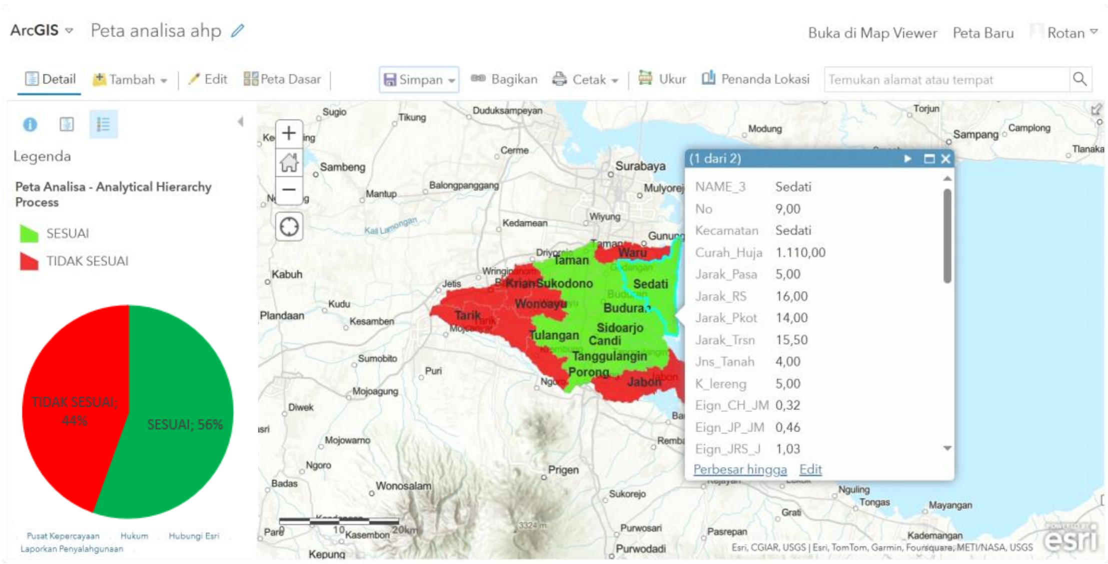
$$V_1 = \frac{2.54}{\begin{array}{c}2.54 + 3.93 + 5.24 + 3.77 + 2.66 + 2.55 \\ +2.78 + 3.10 + 2.83 + 2.92 + 7.77 + 3.55 \\ +2.93 + 3.51 + 2.27 + 3.44 + 2.70 + 3.15\end{array}} = \frac{2.54}{61.64} = 0.04$$

Spatial analysis for Residential Land Suitability using AHP method:

Step 1: From the calculation of the Vector V_i is basis for decision-making. The largest V_i value is the best alternative choice.



(a) Spatial Analysis Results Using WPM Method



(b) Spatial Analysis Results Using AHP Method

Figure 2. Mapping Residential Land Suitability Using a WEB-GIS-Based Multi-Criteria Spatial Analysis Approach

Step 2: Determine the level of relevance, then create a pairwise comparison matrix for each criterion based on the importance values presented in Table 2. The next step is to add the values in the *j-th* column, then repeat this process for each column using Formula 4.

$$\sum_i^7 a_{i1} = a_{11} + a_{21} + a_{31} + a_{41} + a_{51} + a_{61} + a_{71} = 1 + 2 + 2 + 2 + 3 + 3 + 3 = 16$$

Step 3: Calculating alternative priority weights involves dividing each value in the jth column by the value corresponding to the total number of columns until the resulting value for the new column equals 1 using Formula 5.

$$\sum_i^7 a_{i1} = \frac{a_{11}}{\sum_i^7 a_{i1}} + \frac{a_{21}}{\sum_i^7 a_{i1}} + \frac{a_{31}}{\sum_i^7 a_{i1}} + \frac{a_{41}}{\sum_i^7 a_{i1}} + \frac{a_{51}}{\sum_i^7 a_{i1}} + \frac{a_{61}}{\sum_i^7 a_{i1}} + \frac{a_{71}}{\sum_i^7 a_{i1}} = 1/16 + 2/16 + 2/16 + 2/16 + 3/16 + 3/16 + 3/16 = 1$$

Step 4: After summing up all the values in the *i-th* row, divide the total by the number of criteria using Formulas 6 and 7.

$$\sum_{p}^{7} a_{1j} = a_{11} + a_{12} + a_{13} + a_{14} + a_{15} + a_{16} + a_{17}$$
$$= 1 + 0{,}5 + 0{,}5 + 0{,}5 + 0{,}33 + 0{,}33 + 0{,}33 = 3{,}49$$
$$W_1 = \frac{3{,}49}{7} = 0{,}4986$$

Step 5: Calculate CW using Formula 8 to exchange alternative priority weights with criterion priority weights.

$$CW_1 = \sum_j^6 (a_{1j}.W_j) = (a_{11}.w_1) + (a_{12}.w_2) + (a_{13}.w_3) + (a_{14}.w_4) + (a_{15}.w_5) + (a_{16}.w_6) + (a_{17}.w_7) = (1 * 0{,}4986) + (0{,}5 * 0{,}7129) + (0{,}5 * 0{,}9271) + (0{,}5 * 1{,}1414) + (0{,}33 * 2) + (0{,}33 * 2{,}2143) + (0{,}33 * 2{,}4286) = 4{,}0815$$

Step 6: Consistency checking is done by multiplying the pairwise comparison matrix by the priority weights, then dividing the multiplication result by the corresponding priority weights to get the lambda value or eigenvalue using Formula 9.

$$\lambda_1 = \frac{CW_1}{W_1} = 4{,}0815/0{,}4986 = 8{,}1860$$

Step 7: Calculate the maximum lambda by finding the average lambda value using Formula 10.

$$\lambda_{maks} = \frac{8{,}1860 + 6{,}9245 + 6{,}5938 + 6{,}6680 + 7{,}0808 + 7{,}7987 + 8{,}5223}{7} = 7{,}3963$$

Step 8: Calculate the Consistency Index (CI) using Formula (11).

$$CI = \frac{\lambda_{maks} - 7}{7-1} = (7{,}3963 - 7) / 7 - 1 = 0{,}0661$$

Step 9: Calculate the Consistency Ratio (CR) using Formula 12, where if the CR value <0.1, it can be said that the consistency ratio of the calculation is accepted. The *R* variable is the highest score minus the lowest score. and the *K* variable is the number of classification alternatives.

$$CR = \frac{CI}{IR} = \frac{0{,}0661}{1.24} = 0.05\ (consistent)$$
$$R = CR_{max} - CR_{min} = 0.114 - 0.039 = 0.075$$
$$K = 2$$

Step 10: The type of dataset used has a score or weight for analysis. A value is assigned based on the uncertainty factor for the variables reported. This uncertainty factor can be quantified using the Guttman scale [21], [22], derived from Formula 13. This value is based on the uncertainty factor for the described variable class, which can be quantified using the Guttman scale [21], [22] based on Formula 13 with a value based on the uncertainty factor for the variable class.

$$I = \frac{R}{K} = \frac{0.075}{2} = 0.037$$
$$\text{Assessment criteria} = CR_{max} - I = 0.114 - 0.037 = 0.077$$
$$\begin{cases} unsuitable, & if\ CR_i \geq 0.077 \\ suitable, & if\ CR_i < 0.077 \end{cases}$$

The validation test in this study used Cohen's Kappa method. Cohen's Kappa is based on Formula (14) to see the accuracy of the data with the results in Table 6.

Table 6. Analysis Results of AHP and WPM Methods

Criterion	AHP	WPM
Unsuitable	8	2
Suitable	10	16

3.2 Discussions

Finding the P_o value to determine the observed proportional agreement based on Table 6. Where two is not suitably obtained from the results of both methods, ten conforms obtained from the results of both methods, then P_o = (2+10)/18=0.67.

Determining the probability of land unsuitable for settlement using the AHP method, there are eight sub-districts out of 18 sub-districts, or 0.444 from the Guttman Scale, while in the WPM method, unsuitability is in 2 sub-districts out of 18 sub-districts, or 0.111 from the Guttman scale. Then, the total probability of unmatching from both methods is 0.444 * 0.111 = 0.05.

Determining the probability of land suitable for settlement using AHP is ten sub-districts out of 18 sub-districts or 0.556 on the Guttman scale while using the WPM method, there are 16 sub-districts out of 18 sub-districts or 0.889 on the Guttman scale. Then, the total corresponding probability of the two methods is 0.556 * 0.889 = 0.49

Determining the P_e value increases the probability of not being suitable and suitable for land suitability, where $P_e = 0.05 + 0.49 = 0.54$.

Calculating the $K = \frac{(0.67-0.54)}{(1-0.54)} = 0.2$

As shown in Table 4, the test results using Cohen's Kappa to see if the AHP and WPM methods could be used have a "fair" level of agreement, with *K is 0.27*, which means that the methods are 27% accurate. This indicates that the level of agreement is weak/low between the AHP and WPM methods because *K* values between 0.21 and 0.39 are considered minimal [15]. The AHP and WPM approaches do not always produce the same results when applied to the same data, even though there are similarities. These differences may have a major impact on the findings of the investigation. The validity of the findings can be questioned if the two methodologies inconsistently provide the same results [23].

4. Conclusions

The results of this research are the results of spatial analysis to display information on the suitability of new residential land based on the level of condition. The resulting spatial analysis can identify land locations from several categories, namely suitable and unsuitable, using the AHP and WPM methods based on city center distance, market distance, hospital distance, public transport distance, slope, rainfall, and soil type in the district. We checked the accuracy of the calculations using Cohen's Kappa, a statistic that gives a "fair" value of K = 0.27, equal to 27% precision. This was done after using the AHP and WPM methods to do the calculations. Using the same data in one parameter, such as slope data and soil type, but with a different calculation method it can provide small accuracy results. Research that can be developed in the future could improve the prediction results of spatial analysis by increasing accuracy and efficiency in identifying suitable residential land and land unsuitable for use as a residence.

Further research is needed to combine cutting-edge technology, such as machine learning, with artificial intelligence. In addition, the scope of the criteria could be expanded. New factors related to land suitability for housing can be added, and the methodology can also be adapted to be applied in various regions. Continuous refinement and validation of the models that have been built, along with testing and feedback from the real world, will be able to provide a sustainable contribution to producing optimal residential land suitability analysis.

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