Deciding Endemic Area of Dengue Fever using Simple Multi Attribute Rating Technique Exploiting Ranks

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***Abstract* -- Dengue fever is one of the main public health problems in Indonesia. The purpose of this research is to know the endemic area of dengue fever by using AHP and SMARTER method. AHP method is used to define the priority criteria, and SMARTER method is used to determine the final weight of criteria based on Rank Order Centroid (ROC) calculation. The result of research using AHP and SMARTER method get the rank order. The alternative ranks are rank 1 with the highest weight of 0.572 is Tembalang subdistrict. The lowest weight of 0.367 is Tugu and Mijen subdistricts. Alternatives with the highest Weight become the first priority in obtaining policies to cope with dengue cases. After that, followed by the rank order below because priority to tackle dengue fever case is done based on the order of ranking of each alternative. In addition, humidity criteria is very influential on the determination of dengue endemic areas with the highest weight criterion 0.46**.

Keywords—AHP, SMARTER, dengue fever

I. Introduction

Deciding endemic areas of dengue fever has an important role to know the dengue endemic areas. Dengue fever is still one of the main public health problems in Indonesia. Data from around the world shows Asia ranks first in the number of dengue sufferers each year. Meanwhile, from 1968 to 2016, the World Health Organization (WHO) noted Indonesia as the country with the highest dengue fever case in Southeast Asia. Based on statistical data, Semarang is the city most affected by dengue fever because it recorded the highest incidence of dengue fever in the last decade [1].

The variables that are at risk of dengue are temperature, rainfall, and population density [2]. Climate change causes changes in rainfall, temperature, humidity, wind speed so that it affects the terrestrial and ocean ecosystems and affect health. Climate change can affect the proliferation of disease vectors, such as Aedes mosquitoes that cause the spread of dengue virus more easily and wider [3]. In addition, an increased risk of dengue fever cases is increased by being identified in densely populated areas. The amount of temperature and rainfall in dengue epidemics can be a practical reference for early warning of dengue fever [2].

AHP and SMARTER methods have been developed to solve problems in decision making. Analytic Hierarchy Process (AHP) is a decision support method developed by Thomas L. Saaty [4]. This AHP method describes the complex multi-criteria problem into a hierarchy. The process includes assigning attributes to each criterion as well as an assessment of the importance of criteria [5].

SMARTER Method (Simple Multi-Attribute Rating Technique Exploiting Ranks) is a modification of the SMART (Simple Multi-Attribute Rating Technique) method [6]. SMARTER method is modified in terms of weighting criteria used to determine the weight of each criterion based on Rank Order Centroid (ROC) calculation. ROC weighting is one of the many viable weighting methods on MADM with a sequence of importance criteria as it results in high performance in terms of identifying the best alternative with a criteria weight rating [7]. The ROC weight is applied because it presents many advantages and is widely applied to multicriteria models [8].

In the previous study only used one method, such as only the AHP method or only the SMARTER method only. This research uses two methods namely AHP method and SMARTER method. The initial calculation uses the AHP method to determine the priority criteria and subcriteria. After that, the calculation using the SMARTER method to determine the final weight. The SMARTER method is a weighted method based on the importance of the criteria. Therefore, AHP method is needed in determining the level of importance of criteria that will be used in SMARTER method calculation.

The novelty of this research is using AHP and SMARTER method, that is the use of variables based on criteria. These criteria are factors that affect the area endemic dengue fever. The area is endemic due to dengue fever case. The area is endemic due to dengue fever case. Therefore, in the presence of this study, can determine the dengue endemic areas using criteria based on factors that influence the occurrence of dengue fever cases.

II. RELATED WORK

A. *Feature Dataset*

The materials used in this research are rainfall data, air temperature, humidity, wind speed from BMKG of Semarang City and population density data from BPS Semarang City. The data will then be used in the process of calculating the weight of AHP and SMARTER.

The variables in this study consist of criteria and subcriteria. The criteria and subcriteria are:

1. Rainfall with subcriteria> 401 mm (Very High), 301-400 mm (Height), 101-300 mm (Medium), and 1-100 mm (Low)
2. Air Temperature with subcriteria> 35°C (Height), 17°C-35° C (Medium), and <17°C (Low)
3. Moisture with subcriteria> 60% (High), 40-60% (Medium), and <40% (Low)
4. Wind Speed with subcriteria> 22 knots (High), 11-21 knots (Medium), and <10 knots (Low)
5. Population density with subcriteria> 8500 (High), 500-8500 (Medium), and <500 (Low)

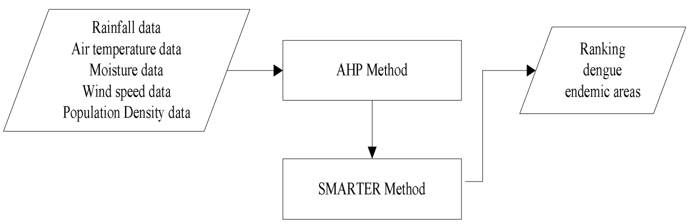
B. *Research Stages*

Stages to be conducted in this study based on data that already existed previously as follows:

- Determination of priority or importance of criteria by using AHP method.
- Determination of final criteria weights by using SMARTER method based on Rank Order Centroid (ROC) weighting. The results of these calculations are then weighted from each alternative.

From the decision making process will get the ranking of dengue fever endemic areas that will be displayed in the form of reports. The stages can be seen in Figure 1.

Figure 1. Information system framework



C. *Analytic Hierarchy Process (AHP)*

AHP is a multicriteria decision-making method introduced by T.L. Saaty. The essence of this method is the pairwise comparison between criteria and decision alternatives made using a 9 unit scale [9].

In AHP method, the following steps are taken [10]:

Step 1. Create a hierarchical structure

Step 2. Create pairwise matrices in pairs

Step 3. Calculates the eigenvectors of each pairwise comparison matrix

The value of the eigenvector is the weight of each element for determining the priority of elements at the lowest hierarchy level until it reaches the goal.

Step 4. Calculates the consistency ratio

What is measured in AHP is the consistency ratio by looking at the consistency index. Consistency is expected to be near perfect to produce a decision that is close to valid.

The value of the Consistency Index is obtained by the equation (1.1) [4]:

$$CI = \frac{\lambda max\text{-}n}{(n\text{-}1)} \tag{1.1}$$

Where CI is expressed as Consistency Index, Max is expressed as the maximum value of the eigenvalue, and n is expressed as matrix size.

If the CR value is less than or equal to 10%, then the result of the assessment is said to be consistent. If the CR value is greater than 10%, then the result of the assessment is said to be inconsistent and should be corrected.
The formula used in calculating CR in the equation (1.2) [4]:

$$CR = \frac{CI}{RI} \tag{1.2}$$

Where CR is expressed as Consistency Ratio, CI is expressed as Consistency Index, and RI is expressed as Random Index.

D. *SMARTER (Simple Multi Attribute Rating Technique Exploiting Ranks)*

SMARTER Method (Simple Multi-Attribute Rating Technique Exploiting Ranks) is a multi-criteria decision-making method proposed by Edwards and Baron in 1994. SMARTER method is a development of SMART (Simple Multi-Attribute Rating Technique). The SMART method was first introduced by Edward in 1971 and was renamed as the SMART method in 1977 [6].

Since its inception, the SMART method has been developed into SMARTS (Simple Multi-Attribute Rating Technique Swing) and then modified and improved by Edward and Baron in 1994 into the SMARTER (Simple Multi-Attribute Rating Technique Exploiting Ranks) method. The difference between the SMARTER method and the SMART and SMARTS methods lies in its weighting. Weighting the criteria on all three methods depends on the order of priority attributes in which the first order is occupied by the attributes considered the most important. In the SMART and SMART methods, the weighting is given directly by the decision maker [6].

But the weighting procedure is deemed to be disproportionate in that any given weight shall reflect the distance and priority of each criteria appropriately. To overcome this, SMARTER method used Rank Order Centroid

(ROC) weighting formula. This SMARTER multicriteria decision making technique is based on the theory that each alternative consists of a number of criteria that have values and each criteria has a weight that describes how important it is compared to other criteria. Weighting in the SMARTER method uses a range between 0 and 1, thus simplifying the calculation and comparison of values in each alternative [6].

E. *Rank Order Centroid (ROC)*

Rank Order Centroid (ROC) weighting method is based on the importance or priority of the criteria [11]. The ROC technique assigns weight to each criteria according to a ranking that begins on a priority level. Usually formed with the statement "Criteria 1 is more important than criteria 2, more important than criteria 3 and so on until the criteria to k, written $Cr_1 \geq Cr_2 \geq Cr_3 \geq \ldots \geq Cr_k$, to determine the weight, given the same rule is $W_1 \geq W_2 \geq W_3 \geq \ldots \geq W_k$ where W_1 is the weight for C_1 criteria [6] :

$$W_1 = (1 + 1/2 + 1/3 + \ldots + 1/K)/K \qquad (1.3)$$
$$W_2 = (0 + 1/2 + 1/3 + \ldots + 1/K)/K$$
$$W_3 = (0 + 0 + 1/3 + \ldots + 1/K)/K$$
$$W_K = (0 + \ldots + 0 + 1/K)/K$$

In general ROC weighting can be expressed in equations (1.4) [6]:

$$W_k = \frac{1}{K}\sum_{i=k}^{K}\left(\frac{1}{i}\right), \qquad i=1,2,\ldots k \qquad (1.4)$$

Where W_k is expressed as Weights criteria to k, and K show Number of criteria.

To determine the weight of the suffix in the equation (1.5) [6]:

$$U_h = \sum_{k=1}^{K} W_k U_h(X_{hk}) \qquad (1.5)$$

Where U_h is expressed as Final score, W_k is expressed as Weights criteria to k, and $U_h(X_{hk})$ show Utility value criteria to k for the alternative to h.

Steps of settlement using SMARTER method that is:

Step 1. Identify the problem, so it can formulate the decision to be taken
Step 2. Define criteria and subcriteria
Step 3. Gives a rating for each criterion and subcriteria
Step 4. Calculates the weighting criteria using ROC weighting
Step 5. Calculates the weight of subcriteria using ROC weighting
Step 6. Calculates the final weight of each criteria

III. Result And Discussion

In this study, system design on report of dengue endemic areas within the framework of information systems (Figure 1). As system input is criterion data (rainfall, air temperature, humidity, wind speed, and population density) while as system output is report of dengue endemic area.

In the input stage, which is to enter the criteria data, the criteria comparison data, the subcriteria comparison data, and the alternative data to the smarter database by the system administrator, the data will be displayed on the dengue endemic areas deciding system.

At the stage of the process, the stage of the process of doing activities in the system, which is to determine the priority criteria and subcriteria based on the value of criteria and subcriteria comparison entered into the system using AHP method. Priority criteria obtained are used in the process of calculating the criteria weight and weight of the criteria using SMARTER method based on Rank Order Centroid (ROC) weighting. To determine alternative spatial obtained from the result of calculation of alternative weighting with SMARTER method.

At the output stage, which is the information generated by the system in the form of reports dengue endemic areas. In the report can be known dengue endemic areas in the period of the moon.

The computation process for calculating the weighting criteria using the AHP and SMARTER methods applied to the system. The code for the criteria and subcriteria is shown in Table 1.

TABLE I. Criteria And Subriteria Code

Code	Criteria	Code	Subcriteria
C1	Humidity	SC11	High
		SC12	Medium
		SC13	Low
C2	Air temperature	SC21	Medium
		SC22	Low
		SC23	High
C3	Rainfall	SC31	High
		SC32	Medium
		SC33	Low
		SC34	Very High
C4	Population density	SC41	High
		SC42	Medium
		SC43	Low
C5	Wind speed	SC51	Medium
		SC52	High
		SC53	Low

The code for the alternative is shown in Table 2.

TABLE II. Alternative Code

Code	Alternative
A1	Tembalang
A2	Candisari
A3	Pedurungan
A4	Gajah Mungkur
A5	Semarang Barat
A6	Semarang Timur
A7	Tugu
A8	Semarang Selatan
A9	Mijen

Code	Alternative
A10	Genuk
A11	Semarang Utara
A12	Banyumanik
A13	Ngalian
A14	Gunung Pati
A15	Gayamsari
A16	Semarang Tengah

A. *Weighting by AHP method*

Here are the steps in determining weights using AHP:

1. Comparison matrix in pairs

   Table 3 and 4 shows a pairwise comparison matrix on criteria and subcriteria.

TABLE III. COMPARISON MATRIX IN PAIRS ON CRITERIA

Criteria	C1	C2	C3	C4	C5
C1	1	2	3	4	5
C2	0.50	1	2	3	4
C3	0.33	0.50	1	2	3
C4	0.25	0.33	0.50	1	2
C5	0.20	0.25	0.33	0.50	1

TABLE IV. COMPARISON MATRIX IN PAIRS ON SUBRITERIA

Sub critera	C1			C2			C3				C4			C5		
	SC 11	SC 12	SC 13	SC 21	SC 22	SC 23	SC 31	SC 32	SC 33	SC 34	SC 41	SC 42	SC 43	SC 51	SC 52	SC 53
SC11	1	2	3													
SC12	0.50	1	2													
SC13	0.33	0.50	1													
SC21				1	2	3										
SC22				0.50	1	2										
SC23				0.33	0.50	1										
SC31							1	2	3	4						
SC32							0.50	1	2	3						
SC33							0.33	0.50	1	2						
SC34							0.25	0.33	0.50	1						
SC41											1	2	3			
SC42											0.50	1	2			
SC43											0.33	0.50	1			
SC51														1	2	3
SC52														0.50	1	2
SC53														0.33	0.50	1

2. Normalization of the matrix

   Table 5 and 6 shows normalization of the matrix on criteria and subcriteria.

TABLE V. NORMALIZATION OF THE MATRIX ON CRITERIA

Criteria	C1	C2	C3	C4	C5
C1	0.44	0.49	0.44	0.38	0.33
C2	0.22	0.24	0.29	0.29	0.27
C3	0.15	0.12	0.15	0.19	0.20
C4	0.11	0.08	0.07	0.10	0.13
C5	0.09	0.06	0.05	0.05	0.07

TABLE VI. NORMALIZATION OF THE MATRIX ON SUBCRITERIA

Sub critera	C1			C2			C3				C4			C5		
	SC 11	SC 12	SC 13	SC 21	SC 22	SC 23	SC 31	SC 32	SC 33	SC 34	SC 41	SC 42	SC 43	SC 51	SC 52	SC 53
SC11	0.55	0.57	0.50													
SC12	0.27	0.29	0.33													
SC13	0.18	0.14	0.17													
SC21				0.55	0.57	0.50										
SC22				0.27	0.29	0.33										
SC23				0.18	0.14	0.17										
SC31							0.48	0.52	0.46	0.40						
SC32							0.24	0.26	0.31	0.30						
SC33							0.16	0.13	0.15	0.20						
SC34							0.12	0.09	0.08	0.10						
SC41											0.55	0.57	0.50			
SC42											0.27	0.29	0.33			
SC43											0.18	0.14	0.17			
SC51														0.55	0.57	0.50
SC52														0.27	0.29	0.33
SC53														0.18	0.14	0.17

3. Weight

   Table 7 and 8 shows the criteria weight and subcriteria weight.

TABLE VII. CRITERIA WEIGHT

Criteria	C1	C2	C3	C4	C5	Weight	Ranking
C1	0.44	0.49	0.44	0.38	0.33	0.42	1
C2	0.22	0.24	0.29	0.29	0.27	0.26	2
C3	0.15	0.12	0.15	0.19	0.20	0.16	3
C4	0.11	0.08	0.07	0.10	0.13	0.10	4
C5	0.09	0.06	0.05	0.05	0.07	0.06	5

TABLE VIII. SUBCRITERIA WEIGHT

Subcriteria	Weight	Ranking
SC11	0.54	1
SC12	0.30	2
SC13	0.16	3
SC21	0.54	1
SC22	0.30	2
SC23	0.16	3
SC31	0.47	1
SC32	0.28	2
SC33	0.16	3
SC34	0.10	4
SC41	0.54	1
SC42	0.30	2
SC43	0.16	3
SC51	0.54	1
SC52	0.30	2
SC53	0.16	3

4. Calculates consistency

   The first step in getting consistency value is by calculating λ max first so that λmaks = 5.066. Next, calculate the Consistency Index (CI) using the equation:

$$CI = (\lambda \text{ max-n})/ \text{ n-1} = (5.066 - 5)/ 5\text{-1} = 0.0165$$

Calculating Consistency Ratio (CR) using equation (1.2) with Ratio Index used 1.12 because using 5 criteria

$$CR = CI/IR = 0.0165/1.12 = 0.0147$$

The value of CR obtained is 0.0147, meaning CR ≤ 0.1. Thus, the weight of the criteria obtained has a consistent value, so the process of processing by using AHP method in determining the criteria weight can be accepted.

B. *Weighting with SMARTER method*

Calculation of criteria and subcriteria weight by SMARTER method based on ROC weighting on equation (1.4).

$$W_k = \frac{1}{K}\sum_{i=k}^{K}\left(\frac{1}{i}\right), \qquad i=1,2,\ldots k \qquad (1.4)$$

The following calculation of the criteria weighting in Table 9.

TABLE IX. WEIGHT CRITERIA

Criteria	Ranking	Weight criteria
C1	1	(1+1/2+1/3+1/4+1/5)/5 = 0.46
C2	2	(0+1/2+1/3+1/4+1/5)/5 = 0.26
C3	3	(0+0+1/3+1/4+1/5)/5 = 0.16
C4	4	(0+0+0+1/4+1/5)/5 = 0.09
C5	5	(0+0+0+0+1/5)/5 = 0.04

For calculating the weight of subcriteria with ROC weighting as same as calculation of criterion weight, following calculation result of the weight of subcriteria in Table 10.

TABLE X. WEIGHT SUBCRITERIA

Subcriteria	Ranking	Weight subcriteria
SC11	1	(1+1/2+1/3)/3 = 0.61
SC12	2	(0+1/2+1/3)/3 = 0.28
SC13	3	(0+10+1/3)/3 = 0.11
SC21	1	(1+1/2+1/3)/3 = 0.61
SC22	2	(0+1/2+1/3)/3 = 0.28
SC23	3	(0+10+1/3)/3 = 0.11
SC31	1	(1+1/2+1/3+1/4)/4 = 0.52
SC32	2	(0+1/2+1/3+1/4)/4 = 0.27
SC33	3	(0+0+1/3+1/4)/4 = 0.15
SC34	4	(0+0+0+1/4)/4 = 0.06
SC41	1	(1+1/2+1/3)/3 = 0.61
SC42	2	(0+1/2+1/3)/3 = 0.28
SC43	3	(0+10+1/3)/3 = 0.11
SC51	1	(1+1/2+1/3)/3 = 0.61
SC52	2	(0+1/2+1/3)/3 = 0.28
SC53	3	(0+10+1/3)/3 = 0.11

The subsequent calculation by multiplication of the weight of criteria by the weight of subcriteria in equation (1.5)

$$U_h = \sum_{k=1}^{K} W_k\, U_h(X_{hk}) \qquad (1.5)$$

Here are the final weights are shown in Table 11.

TABLE XI. CALCULATION OF FINAL WEIGHT

Weight	Weight Criteria	Subcriteria	Weight Subcriteria	The Final Weight
C1	0.46	SC11	0.61	0.46 x 0.61=0.281
		SC12	0.28	0.46 x 0.28=0.129
		SC13	0.11	0.46 x 0.11=0.051
C2	0.26	SC21	0.61	0.26 x 0.61=0.159
		SC22	0.28	0.26 x 0.28=0.073
		SC23	0.11	0.26 x 0.11=0.029
C3	0.16	SC31	0.52	0.16 x 0.52=0.083
		SC32	0.27	0.16 x 0.27=0.043
		SC33	0.15	0.16 x 0.15=0.024
		SC34	0.06	0.16 x 0.06=0.010
C4	0.09	SC41	0.61	0.09 x 0.61=0.055
		SC42	0.28	0.09 x 0.28=0.025
		SC43	0.11	0.09 x 0.11=0.010
C5	0.04	SC51	0.61	0.04 x 0.61=0.024
		SC52	0.28	0.04 x 0.28=0.011
		SC53	0.11	0.04 x 0.11= 0.004

C. *Alternative ranking with SMARTER method*

After obtaining the final weight, the next step is an alternative weighting using SMARTER method by summing the final weight of each criterion against the subcriteria. The calculation of alternative weights using SMATER method is shown in Table 12.

TABLE XII. CALCULATION OF ALTERNATIVE WEIGHT

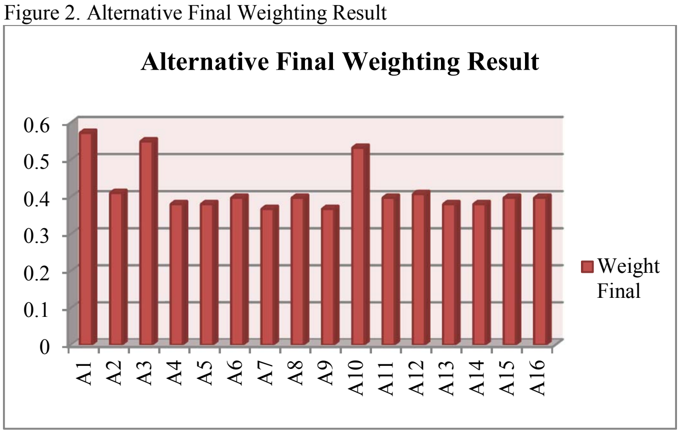
Sub critera	C1			C2			C3				C4			C5		
	SC 11	SC 12	SC 13	SC 21	SC 22	SC 23	SC 31	SC 32	SC 33	SC 34	SC 41	SC 42	SC 43	SC 51	SC 52	SC 53
A1	0.281			0.159			0.083					0.025		0.024		
A2		0.129		0.159				0.043			0.055			0.024		
A3	0.281			0.159				0.043			0.055				0.011	
A4		0.129		0.159				0.043				0.025		0.024		
A5		0.129		0.159				0.043				0.025		0.024		
A6		0.129		0.159				0.043			0.055				0.011	
A7		0.129		0.159				0.043				0.025			0.011	
A8		0.129		0.159				0.043			0.055				0.011	
A9		0.129		0.159				0.043				0.025			0.011	
A10	0.281			0.159				0.043				0.025		0.024		
A11		0.129		0.159				0.043			0.055				0.011	
A12		0.129		0.159			0.083					0.025			0.011	
A13		0.129		0.159				0.043				0.025		0.024		
A14		0.129		0.159				0.043				0.025		0.024		
A15		0.129		0.159				0.043			0.055				0.011	
A16		0.129		0.159				0.043			0.055				0.011	

Table 13 shows that the alternative A1 is rank 1 with the highest final weight 0.572. Alternative A1 is Tembalang subdistrict. The alternative A7 and A9 are rank 8 with the lowest final weight 0.367. The alternative A7 and A9 are Tugu and Mijen subdistrict. The final weight of the alternative and ranking results shown in Table 13.

TABLE XIII. RESULT OF ALTERNATIVE FINAL WEIGHT AND RANKING

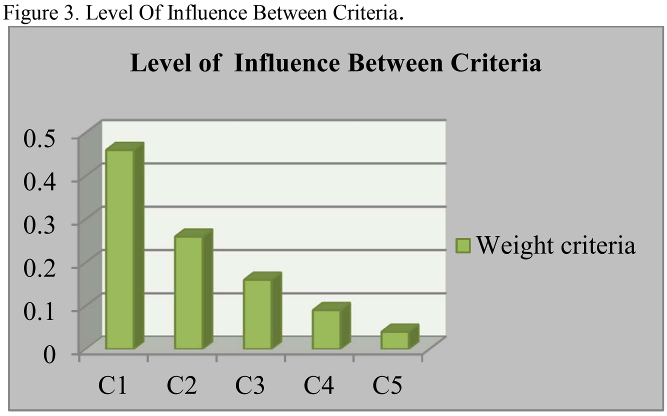
Alternative	Final Weight	Ranking
A1	0.572	1
A2	0.41	4
A3	0.549	2
A4	0.38	7
A5	0.38	7
A6	0.397	6
A7	0.367	8
A8	0.397	6
A9	0.367	8
A10	0.532	3
A11	0.397	6
A12	0.407	5
A13	0.38	7
A14	0.38	7
A15	0.397	6
A16	0.397	6

Figure 2. Alternative Final Weighting Result



Humidity criteria is very influential on endemic areas of dengue fever with the highest criteria weight 0.46. The degree of influence among the criteria is shown in figure 3.

Figure 3. Level Of Influence Between Criteria.



IV. CONCLUSION

The result of research using AHP and SMARTER method get the rank order. The alternative ranks are rank 1 with the highest weight of 0.572 is Tembalang subdistrict. The lowest weight of 0.367 is Mijen and Tugu. Alternatives with the highest weight become the first priority in obtaining policies to cope with dengue cases. After that, followed by the rank order below because priority to tackle dengue fever case is done based on the order of ranking of each alternative. Thus, efforts to prevent the increasing number of cases of dengue fever in the city of Semarang can be reduced.

In addition, humidity criteria is very influential on the determination of dengue endemic areas with the highest weight criterion 0.46. The higher the humidity, the greater the area is endemic dengue fever. After that followed by other criteria.

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