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THE USE OF SMART AND WEBGIS VISUALIZATION METHODS IN RECOMMENDING REGIONS THAT REQUIRE CLEAN WATER SUPPLY

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Abstract

The increasing population is inversely proportional to the amount of clean water that can be consumed. The potential for a clean water crisis should be known from in advanced on in order to minimize its impact. If the community lacks awareness of the potential for a clean water crisis, then the impact will be greater. Therefore, this paper aims to make an application that can recommend areas that require clean water. The parameters used to recommend areas that require clean water were water discharge, the distance between residential arenas and water sources, the total population, and water management installation technology. The application was made using SMART method to classify the area as safe, potential, critical or very critical, and the visualization was made using WEBGIS. This research has proven that the SMART Method as one of the Multiciteria Decision Aid (MCDA) methods can be used in water management. Applications that have been made can be utilized by the Regional Water Supply Company (PDAM) Tirtawening in the city of Bandung.

Keywords: Recommendation system, SMART, WEBGIS.

1. Introduction

Simple Multi Attribute Rating Technique (SMART) is a method that can be used to assist in decision making [1,2]. The advantage of the SMART method is that it is easy to use for various types of weight assignment techniques such as relative or absolute [3]. SMART can be applied to problems that occur in the environment, construction, transportation and others [3]. WEBGIS can be considered as integration between internet technology and geographic information systems [4]. The spatial information generated by a geographic information system (GIS) regarding water availability in an area is very important in managing sustainable water resources [5].

Based on the advantages of SMART and WEBGIS, this paper applied these two methods to determine priority areas that require clean water supply. Clean water is the main factor for survival and without clean water almost all life processes will not take place. Population growth and the pace of development have resulted in environmental degradation, especially surface water quality. This situation occurs in urban areas with large populations. The quality of raw water tends to decrease and this has become the center of attention in the provision of clean water in Indonesia [6]. The amount of available clean water that can be explored and consumed is not sufficient for the growing population in Indonesian. The potential for a clean water crisis should be identified beforehand in order to minimize its impact. If the community lacks awareness of the potential for a clean water crisis, then the impact will be greater.

Solving the problem regarding water distribution is very important. This is reinforced by many studies related to water distribution, and four of the studies is discussed. The first study was about estimating the demand for water distribution networks using the Particle Swarm Optimization (PSO) algorithm. The study stated that the estimation can provide important information related to monitoring and control systems for water distribution [7]. The second study was about the application of geographic information systems to assess the availability and needs of water demand [5]. The third study stated that the combination of GIS and hydraulic modelling resulted in more effective water distribution management [8]. The fourth study also incorporated GIS with an artificial neural network (ANN) model and the integration could prioritize the sequence of pipe replacement in the water distribution network so that it could be more effective and efficient [9]. Based on the four studies, it can be concluded that the problems related to the environment such as water distribution can be solved by combining GIS applications and methods that can support decision making. This research will approach a different method from the 4 studies above, namely by using the SMART method as one of the MCDA methods.

This study analyzes the areas that require water supply systems so that they can help areas that experience a clean water crisis. Based on the aforesaid problems, an information system is needed to analyze areas that lack clean water, by processing textual and spatial data which results in a decision-making system in the form of recommendations for regions that require clean water supply using the Simple Multi Attribute Rating Technique (SMART) method by utilizing WEBGIS. The use of the MCDA method can involve stakeholders as planners in making decisions [10]. With this system, it is expected that relevant agencies or governments can easily analyze areas that have experienced clean water crisis so that they can assist in planning the development of water supply systems and reduce the clean water crisis.

2. Method

In accordance with the aim of this paper, which is to produce a system that is able to recommend areas that require clean water supply, there are several stages as shown in Fig. 1. Figure 1 shows three main stages, namely the determining of attributes, the implementation stage of the smart method and the visualization stage using GIS. The first stage is to determine the correct attributes to recommend an area that requires clean water supply. To determine the attributes, the method used is by interview and literature study. Interviews were conducted to obtain the attributes used in determining the area requires a water supply system, at this stage the researchers conducted interviews with expert experts namely the Head of Water Supply Engineering Planning PDAM Bandung City.

The second stage is to implement the steps of the SMART method. The SMART method is applied to The Application to Recommend for Regions that Receive Clean Water Supply. The stages of the SMART method are Give attribute weight to each attribute by using 1-100 intervals for each attribute for the most important priority. Calculate the normalization of each attribute by comparing the value of attribute weights with the number of attribute weights. Rating of the attributes for each alternative. Determine the utility value by converting the attribute values on each attribute to the default data values. The final value by multiplying the value obtained from normalizing the attribute weights by the utility value. Then add up the value of the multiplication.

The final stage is to visualize the recommendations of areas that require clean water using GIS. GIS visualization uses the arcgis application, the data used are the administrative boundaries of the City of Bandung and the territorial boundaries in PDAM Tirtawening in the City of Bandung. Spatial data obtained from calculations with the SMART method that has been done previously. Spatial data processing uses a feature of the arcgis application, namely arcmap. The next step is to publish it to the web using arcgis online.

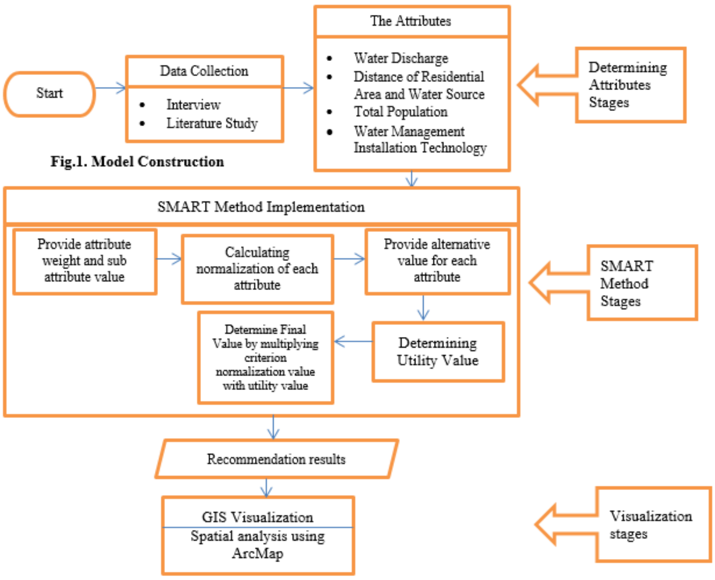

Fig. 1. Model construction.

3. Results and Discussion

This section discusses the steps in implementing the SMART method by using research data and how to visualize them into WEBGIS.

3.1. Implementation of SMART method

3.1.1. Attribute weight and sub attribute value

Determining the attributes was based on the results of interviews with a source named Mr. Jhoni Wahdanu (The Head of Drinking Water Engineering Planning Division of PDAM Bandung City). Weighting to compare between attributes, the weighting in this study shows that these attributes have a more important role in determining the need for clean water in an area.

Whereas for the weight of attributes, sub attributes and their values, they were determined based on an interview with The Head of Drinking Water Engineering Planning Division of PDAM Bandung City in Table 1.

Table 1. Attributes and recommendation weight of areas that require water supply.

No.	Attribute	Weight
1.	Water discharge	40
2.	Distance of residential area and water source	30
3.	Total population	20
4.	Water management installation technology	10
Total		100

3.1.1.1. Water discharge

The amount of water discharge becomes a preview of an area experiencing a water crisis, the less the amount of water discharge that the area has, both surface water and other water sources, then the area may experience clean water crisis, and vice versa. Table 2 presents the sub attributes of water discharge and with its value scale:

Table 2. Sub attributes of water discharge.

No.	Sub Attribute	Value Scale
1.	Very high	1
2.	High	2
3.	Low	3
4.	Very low	4

3.1.1.2. Distance of residential areas and water sources

The distance of residential areas and water sources is one of the considerations in determining the areas that experience water crisis. The further the distance between the residential areas and the water sources, the area may experience water crisis since it is difficult to get raw water, and vice versa. In Table 3, the sub attributes of the distance of residential areas and water sources and their value scales is presented.

Table 3. Sub attributes of distance of residential areas and water sources.

No.	Sub Attribute	Value Scale
1.	Very close	1
2.	Close	2
3.	Far	3
4.	Very far	4

3.1.1.3. Total population

The more the population, the need for water is also increasing, and therefore it can cause water crisis and it requires a water supply system. Vice versa, if the population is small, the need for clean water is low. Table 4. shows the sub attributes of the total population along with the value scale.

Table 4. Sub attributes of total population.

No.	Sub Attribute	Value Scale
1.	5.000 – 10.000	1
2.	10.001 – 15.000	2
3.	15.001 – 20.000	3
4.	20.001 - >25.000	4

3.1.1.4. Water management installation technology

Water treatment installations are sources of water used for channel water to residents. Water treatment installations include river water, surface water, bulk water, and ground water, both deep and shallow. In Table 5, the water management installation technology and the value scale is shown.

Table 5. Sub attribute of water installation technology.

No.	Sub Attribute	Value Scale
1.	Surface water	1
2.	Bulk water	2
3.	Spring	3
4.	Drilled well	4

3.1.2. Normalization of each attribute

The calculation of the normalization of each attribute weight is described in Table 6 by using the following formula [1]:

$$\text{Normalization } Wj = Wj/(\sum Wj) \qquad (1)$$

Table 6. Normalization of attributes.

No.	Attribute	Attribute Weight (Wj)	Normalization of Attribute Weight
1.	Water discharge (C1)	40	40/100 = 0.4
2.	Distance of residential areas and water sources (C2)	30	30/100 = 0.3
3.	Total population (C3)	20	20/100 = 0.2
4.	Water management installation technology (C4)	20	10/100 = 0.1

3.1.3. Alternative value of each attribute

The assessment for alternative value for each attribute used data sampling in random.org application because PDAM Tirtawening in Bandung did not have actual data that were suitable with the research conducted. The steps of using random.org were, first input the minimum and maximum scale values, and then click the random button. After that, the random result values were provided. The alternative value of each attribute is described in Table 7.

Table 7. Alternative value of each attribute.

No.	District	Sub-District	C1	C2	C3	C4
1.	Bandung Kulon	Caringin	4	3	2	3
2.	Bandung Kulon	Cibuntu	3	4	3	2
3.	Bandung Kulon	Cigondewah Kaler	3	2	4	2
4.	Bandung Kulon	Cigondewah Kidul	4	3	1	4
….	….	….	….	….	….	….
36.	Andir	Maleber	1	3	3	2

3.1.4. Utility value

In determining the utility value, the following formula was used.:

$$u_i(a_i) = \left(\frac{Ccout - Cmin}{Cmax - Cmin} * 100\% \right) \quad (2)$$

description:

ui(ai) = utility value of criterion i for the i

Cmax = maximum criterion value

Cmin = minimum criterion value

Ccout = value of criterion i

For the calculation of the utility value, the following examples were taken from the Caringin, Cibuntu, Cigondewah Kaler and Cigondewah Kidul sub-districts.

1. Utility value of attribute C1
   Caringin(C1) = $\left(\frac{4-1}{4-1} * 100\% \right)$ = 1
   Cibuntu(C1) = $\left(\frac{3-1}{4-1} * 100\% \right)$ = 0.67
   Cigondewah Kaler(C1) = $\left(\frac{3-1}{4-1} * 100\% \right)$ = 0.67
   Cigondewah Kidul(C1) = $\left(\frac{4-1}{4-1} * 100\% \right)$ = 1
2. Utility value of attribute C2
   Caringin(C2) = $\left(\frac{3-1}{4-1} * 100\% \right)$ = 0.67
   Cibuntu(C2) = $\left(\frac{4-1}{4-1} * 100\% \right)$ = 1
   Cigondewah Kaler(C2) = $\left(\frac{2-1}{4-1} * 100\% \right)$ = 0.33
   Cigondewah Kidul(C2) = $\left(\frac{3-1}{4-1} * 100\% \right)$ = 0.67
3. Utility value of attribute C3

Caringin(C3) = $\left(\frac{2-1}{4-1} * 100\% \right)$ = 0.33
Cibuntu(C3) = $\left(\frac{3-1}{4-1} * 100\% \right)$ = 0.67
Cigondewah Kaler(C3) = $\left(\frac{4-1}{4-1} * 100\% \right)$ = 1
Cigondewah Kidul(C3) = $\left(\frac{1-1}{4-1} * 100\% \right)$ = 0

4. Utility value of attribute C4
   Caringin(C4) = $\left(\frac{3-1}{4-1} * 100\% \right)$ = 0.67
   Cibuntu(C4) = $\left(\frac{2-1}{4-1} * 100\% \right)$ = 0.33
   Cigondewah Kaler(C4) = $\left(\frac{2-1}{4-1} * 100\% \right)$ = 0.33
   Cigondewah Kidul(C4) = $\left(\frac{4-1}{4-1} * 100\% \right)$ = 1

3.1.5. Alternative total value

Determining the alternative total value used the following formula [1,11].

$$U(a_i) = \sum W_j U_i(a_i) \quad (3)$$

description:

$U(a_i)$ = alternative total value

W_j = results of attribute weight normalization

$U_i(\mathrm{a_i})$ = results of utility vale calculation

For the calculation of the alternative total values, the following examples were taken from the Caringin, Cibuntu, Cigondewah Kaler and Cigondewah Kidul sub-districts.

1. Caringin(C1) = 1 * 0.4 = 0.4
   Caringin(C2) = 0.67 * 0.3 = 0.2
   Caringin(C3) = 0.33 * 0.2 = 0.06
   Caringin(C4) = 0.67 * 0.1 = 0.06
2. Cibuntu(C1) = 0.67 * 0.4 = 0.26
   Cibuntu(C2) = 0.1 * 0.3 = 0.3
   Cibuntu(C3) = 0.13 * 0.2 = 0.02
   Cibuntu(C4) = 0.33 * 0.1 = 0.03
3. Cigondewah Kaler(C1) = 0.67 * 0.4 = 0.26
   Cigondewah Kaler(C2) = 0.33 * 0.3 = 0.1
   Cigondewah Kaler(C3) = 0.1 * 0.2 = 0.2
   Cigondewah Kaler(C4) = 0.33 * 0.1 = 0.03
4. Cigondewah Kidul(C1) = 1 * 0.4 = 0.4
   Cigondewah Kidul(C2) = 0.67 * 0.3 = 0.2
   Cigondewah Kidul(C3) = 0 * 0.2 = 0
   Cigondewah Kidul (C4) = 1 * 0.1 = 0.1

3.1.6. Recommendation values

The results of the calculation of the data were classified into 4 categories, namely safe, potential, critical, and very critical. The 'safe' category means that the area does not experience a clean water crisis, the 'potential' category means that the area can potentially experience a water crisis, the 'critical' category means that the area is experiencing a water crisis so it needs a water supply system, and 'very critical' category means that the area is very critical and it is highly recommended to provide a clean water supply system. The value scale given is as follows:

- 0.1 – 0.33 = safe
- 0.34 – 0.49 = potential
- 0.50 – 0.65 = critical
- 0.66 > = very critical

The final results of the calculated total value are described in Table 8:

Table 8. Final Results of the Calculation

No	Sub-District	C1	C2	C3	C4	Result	Category
1.	Caringin	0.4	0.2	0.06	0.06	0.73	Very critical
2.	Cibuntu	0.26	0.3	0.02	0.03	0.62	Critical
3.	Cigondewah Kaler	0.26	0.1	0.2	0.03	0.6	Kritis
4.	Cigondewah Kidul	0.4	0.2	0	0.1	0.7	Very critical
….	……	……	……	……	……	……	……
36.	Maleber	0	0.2	0.13	0.03	0.36	Potential

3.2. GIS visualization

The data obtained from PDAM was in the form of *.shp file processed using a feature from Arcgis namely ArcMap. ArcMap is an application that is used for mapping processes using computers. ArcMap has the ability to process, visualize, build new spatial databases, query, edit, create map design, analyze, and create final results. The following is a spatial analysis of the research conducted using ArcMap.

3.2.1. Add data

The *.shp file of the districts and sub-districts in Bandung City were imported and then clipping, which is cropping an area based on other areas was done. The sub district’s *.shp file was clipped with the district’s *.shp file and adjusted based on the attributes used. Figure 2 is the result of the clipping of the district and sub-district.

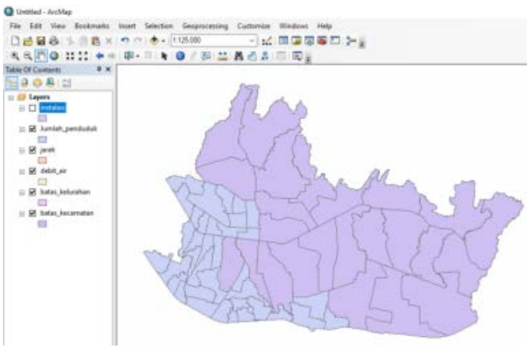

Fig. 2. Clip of district and sub district.

3.2.2. Open attribute table

The data were entered in accordance with the calculations conducted in the previous stage. The same process was done for all attributes. Figure 3 is a list of attributes for installation data.

Table

instalasi

FID	Shape *	id	gid	nama_kel	kode_kel	instalasi
0	Polygon	1	2	Kel. Ciroyom	BD4	0,1
1	Polygon	2	3	Kel. Dunguscariang	BD3	0,1
2	Polygon	3	5	Kel. Garuda	BD1	0,06
3	Polygon	4	12	Kel. Husein Sastranegara	BC2	0,1
4	Polygon	12	6	Kel. Maleber	BD2	0,03
5	Polygon	14	8	Kel. Pamoyanan	BC1	0,1
6	Polygon	16	10	Kel. Pajajaran	BC4	0,1
7	Polygon	17	13	Kel. Sukaraja	BC6	0,06
8	Polygon	37	54	Kel. Batununggal	GC4	0,06
9	Polygon	19	49	Kel. Wates	GC1	0
10	Polygon	91	122	Kel. Cigondewah Rahayu	TE6	0,06
11	Polygon	68	92	Kel. Cibaduyut Wetan	TC4	0,06
12	Polygon	69	94	Kel. Cirangrang	TD6	0
13	Polygon	71	101	Kel. Cigondewah Kidul	TE7	0,1
14	Polygon	73	97	Kel. Margasuka	TD5	0,06
15	Polygon	74	99	Kel. Margahayu Utara	TD4	0,1
16	Polygon	75	100	Kel. Kebonlega	TC2	0,06
17	Polygon	78	96	Kel. Mekarwangi	TC5	0
18	Polygon	80	111	Kel. Caringin	TE4	0,06
19	Polygon	81	112	Kel. Babakan	TD1	0
20	Polygon	84	119	Kel. Cibuntu	TE2	0,03
21	Polygon	87	109	Kel. Gempolsari	TE5	0,06
22	Polygon	89	120	Kel. Cigondewah Kaler	TE8	0,03
23	Polygon	90	121	Kel. Cijerah	TE1	0,03
24	Polygon	107	4	Kel. Arjuna	BC3	0,03
25	Polygon	108	11	Kel. Cempaka	BD6	0,06
26	Polygon	119	93	Kel. Cibaduyut Kidul	TC6	0
27	Polygon	120	95	Kel. Cibaduyut	TC3	0,06
28	Polygon	121	104	Kel. Babakan Ciparay	TD2	0,06
29	Polygon	135	48	Kel. Kujangsari	GC3	0,06
30	Polygon	136	51	Kel. Mengger	GC2	0
31	Polygon	138	105	Kel. Situ Saeur	TC1	0,06
32	Polygon	139	117	Kel. Sukahaji	TD3	0,06
33	Polygon	140	118	Kel. Warungmuncang	TE3	0,06
34	Polygon	13	7	Kel. Pasirkaliki	BC5	0,1
35	Polygon	122	1	Kel. Kebon Jeruk	BD5	0,03

Fig. 3. Table of attributes.

3.2.3. Union

The layers that were combined include the layer of water discharge, distance, population, and installation. This was done to obtain one layer as a map of the area that requires a water supply system with the attributes. Figure 4 is a combination of layers from the attributes of determining the recommendations of regions that require clean water supply.

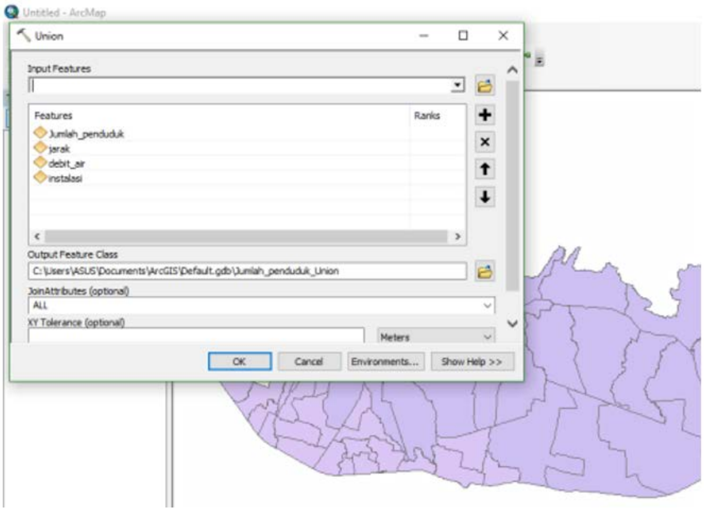

Fig. 4. Union.

3.2.4. Field calculator

After the data from each layer (data of water discharge, distance, and population) were combined, Fig. 5 describes the addition of total field to accommodate the number of values of each attribute by using the Field Calculator process.

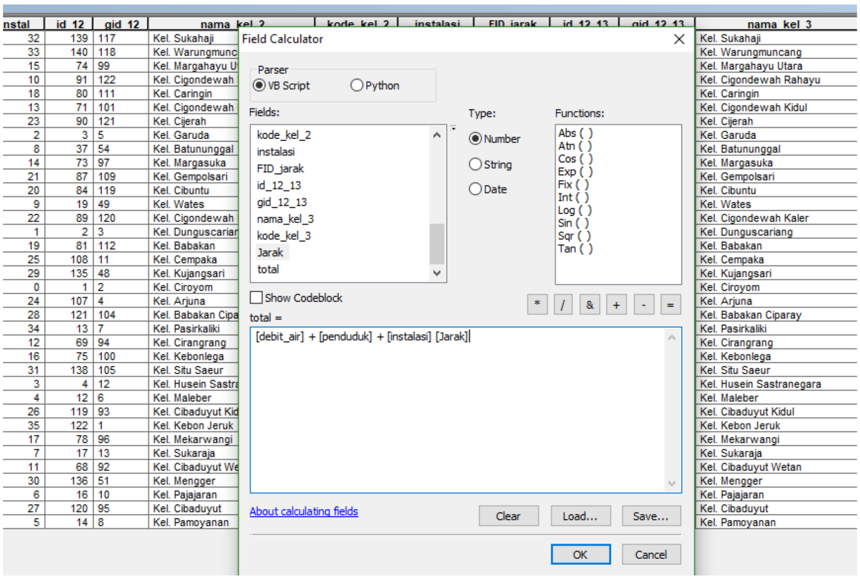

Fig. 5. Field calculator.

3.2.5. Layer properties (Symbology)

After the calculation, the classification of the total table was carried out. At this stage, the classification of the map was divided into several classes. The results of the assessment were automatically divided into predefined classes with different color symbols. The darker areas meant that the area was recommended to receive a clean water supply system. As in Fig. 6, the assessment results were divided into 4 classes with the following description.

0.100 – 0.330 = safe, 0.331 – 0.490 = potential, 0.491 – 0.650 = critical and 0.651 – 0.850 = very critical

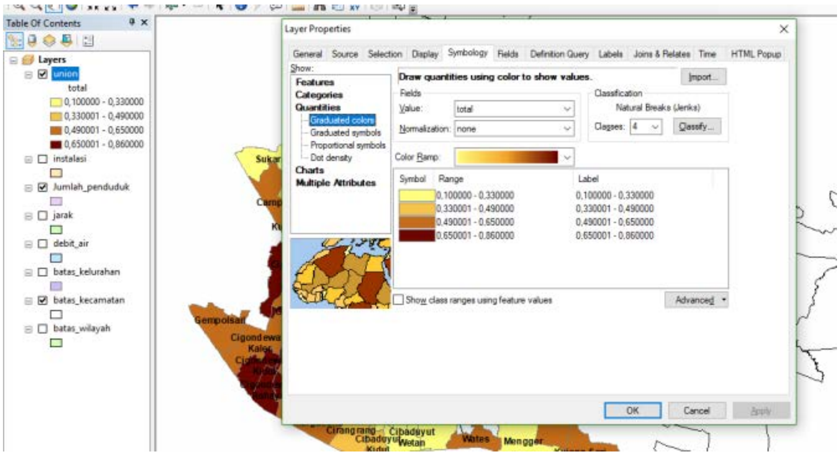

Fig. 6. Layer properties.

3.2.6. Publication to the WEB

After processing the spatial data, the map was published to the web by importing the previously processed product in the form of **.shp* file to the online *arcgis* web. After importing the data, the layers were displayed in the GIS web.

3.3. The application to recommend for regions that receive clean water supply

The database consists of 5 interrelated tables as can be seen in Fig. 7. The implementation of the database used MySQL software.

Figures 8, 9 and 10 user interfaces are displayed in the application to recommend areas that receive clean water supply.

Figure 8 shows the attribute data page that has been added along with the weight of each attribute. The administrator can edit or delete attribute data that have been added. The data are presented in table form so that it is easier for the administrators to process attribute data.

Figure 9 displays an alternative page. The page shows alternative data that have been added. The amount of data displayed is in accordance with the settings made by adjusting show entries, and then the amount of data displayed will be adjusted. The alternative data can also be edited or deleted.

Figure 10 is an explanation of the map page interface. Information on recommended regions that require clean water supply system is presented in the form of a Geographic Information System, which is presented in a digital map. This is done to make ease the users in obtaining information only by looking at a map of which areas that that need clean water supply. There is several different colour information to make it easier for users to differentiate the recommendations.

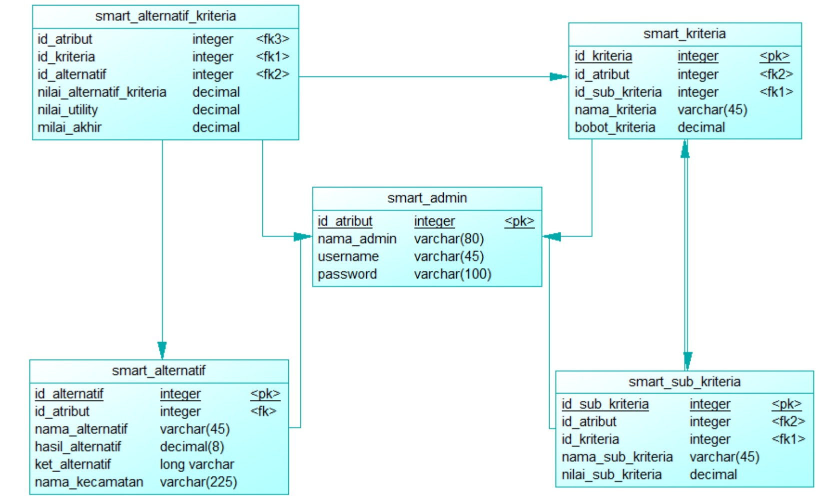

Fig. 7. Application database to recommend areas that receive clean water supply.

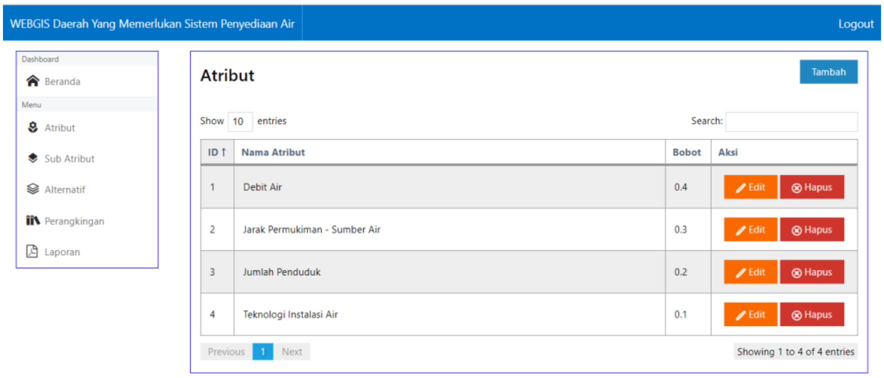

Fig. 8. User interface for attribute input.

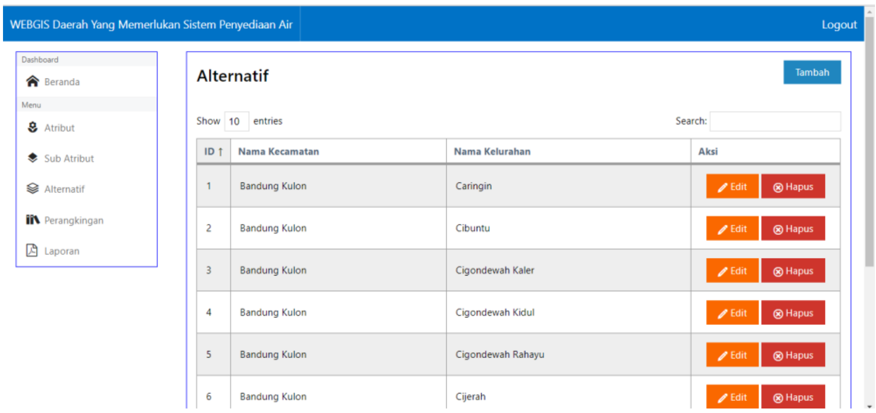

Fig. 9. user interface for alternative input.

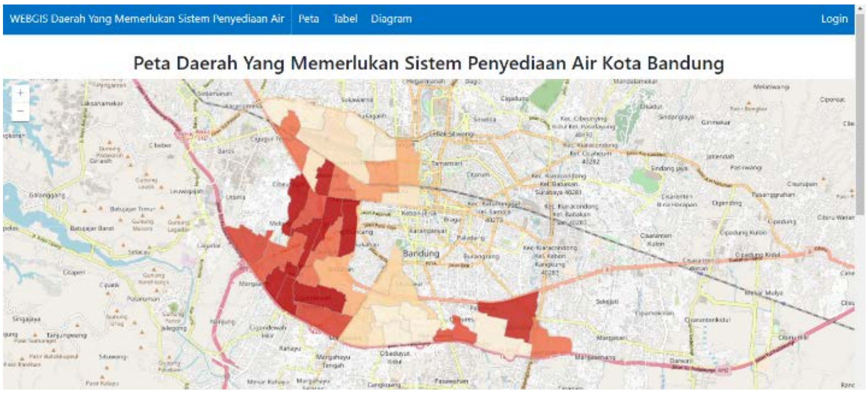

Fig. 10. User interface of map page.

4. Conclusions

There are four attributes used for Areas that Require clean Water Supply, namely Water discharge, Distance of residential areas and water sources, Total population and Water management installation technology. The SMART method can be used to classify areas that need clean water with the statuses of very critical, critical, potential, or safe. Moreover, GIS web visualization can facilitate users in determining areas that need water supply system because it is visualized in the form of digital maps. Users of this application are Tirtawening Regional Water Supply Company (PDAM) in the city of Bandung.

This research has a limitation that the system can only display maps from 6 districts in the city of Bandung that are used as research data. The 6 districts are Bandung Kulon District, Bandung Kidul District, Bojong Loa Kidul District, Babakan Ciparay District, Cicendo District and Andir District. Further research is suggested on developing a GIS system that can be connected directly to the database system, so that if there is a change in the database, the GIS can change accordingly.

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