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To cite this article: A Hijriani and A Cahyani 2021 *J. Phys.: Conf. Ser.* **1751** 012033

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Web GIS based assessment using SAW methods to identify high risk areas of tuberculosis transmission and incidence in Bandar Lampung City

A Hijriani^{1,1}, A Cahyani^{2,2}

^{1,2} Department of Computer Science, Faculty of Mathematics and Natural Sciences, University of Lampung, Jl. Sumantri Brojonegoro no 1, Bandar Lampung, Indonesia

email: astria.hijriani@fmipa.unila.ac.id¹, asti.cahyani1531@students.unila.ac.id²

Abstract Tuberculosis (TB) is still a major problem in the public health sector, even in 2016 Indonesia was included in the five countries with the highest TB case burden in the world. In 2017, the number of TB cases in Lampung Province was 7,040 cases and one of the obstacles faced was the tendency for TB sufferers to be difficult to open so that many cases were not detected. Based on these facts, a Geographical Information System (GIS) is proposed which can process data into maps to see high risk areas where TB disease was found in Bandar Lampung. It will make it easier for health agencies to make policies in handling or preventing TB disease in Bandar Lampung. In this study, a decision-making system with Simple Additive Weighting (SAW) method was also proposed to produce a map of the area with the level of TB risk factors. The criteria used to summarize the weights are TB cases, population density, mortality, healthy and clean behavior, and health facilities. The result of data processing is presented in a color polygon map that has 4 levels of risk factors, namely very high, high, medium, and low.

Keyword: GIS, Simple Additive Weighting (SAW), Tuberculosis

1. Introduction

Geographical Information System (GIS) is an information system that performs data processing and presents the results in map form. The data used in this GIS implementation is in the form of spatial data or data that contains spatial elements from geographic objects on the earth's surface and attribute data or data in the form of text or numbers that serve to explain the characteristics of the object [1]. GIS also has a bigger function, because the data that is managed, manipulated and analyzed will be reproduced in the form of spatial graphics for various planning and mapping [2]. The benefits of using GIS are now widely used in various fields, one of which is in the field of Public Health.

Public Health is the application of integration from medical, sanitation, and social science in an effort to prevent disease that affect society, prolong life, and improve public health [3]. This discussion in the field of public health is closely related to epidemiology or the spread of health problems in society and the factors that influence it. Descriptive epidemiology that describes the spread of disease in three dimensions of place, time, and also human population [4]. This is where the compatibility of GIS technology in the world of epidemiology is found, with the dimensions of place/location and population



in descriptive epidemiology that are closely related to geography. This study will explain the importance of GIS technology in epidemiology to describe how the spread of disease occurs in society and visualize it in the form of a map, so that health agencies as policy makers in handling the prevention of the spread of this disease can be helped.

Tuberculosis (TB) is a disease that caused by mycobacterium tuberculosis bacteria and can be transmitted when a TB sufferer coughs or sneezes. TB disease is still a serious problem in the public health sector, not only in Indonesia but also in the world. In 2016 globally there were 10.4 million incidents of TB cases, equivalent to 120 cases per 100.000 population. Indonesia is one of the five countries with the highest incidence of TB cases in the world with the number of TB cases as many as 420.994 cases [5]. Based on the report, this disease is still ranked as the 10th highest causes of death in the world [5]. One of the obstacles faced in efforts to control TB disease is the tendency for TB sufferers to be difficult to open up, so that many TB cases have not been detected, even if detected and treated but not reported to the Health Agency.

The number of TB cases in Lampung Province in 2017 reach 7,040 cases [6] and according to the Head of the Lampung Provincial Health Office, cooperation from all parties is needed to work hand in increasing TB detection, so that the 2050 target of TB-free Lampung can be fulfilled [7]. As one of the early anticipation efforts, the Bandar Lampung City Health Office as the Health Agency authorized to handle TB disease in Bandarlampung City needs to have a system that can assist in monitoring TB disease in Bandarlampung City. This system will facilitate policy making in handling or preventing TB disease in Bandarlampung.

There has been research on [8] before, to determine the risk factors for TB transmission with a phenomenological approach in one of the urban villages in Bandarlampung, data analysis was carried out using the Milles and Huberman model. The Bandar Lampung City Health Office also has an Integrated Tuberculosis Information System (ITIS) which is used for inputting data on the number of TB sufferers in each District in Bandarlampung City. However, the obstacle faced is the tendency for TB sufferers to be difficult to open so that many TB cases are not reported to the Health Agency. Based on a series of facts, it is important for the Bandar Lampung City Health Office to utilize GIS. With the existence of GIS technology that can carry out mapping, it will greatly help the Bandar Lampung City Health Office if GIS can be applied to mapping TB disease, so that the process of monitoring the spread and information of an area with a level of risk of TB disease can be easily identified.

To monitor areas with the level of TB contact risk factors in Bandarlampung City, GIS technology needs to be combined with a decision-making system to be able to produce maps of areas with the level of TB contact risk factors. On research [9] which uses the MADM method in GIS as a means of analyzing target high-risk areas and monitoring TB incidences in the country. MADM itself is a method of finding the best alternative and making decisions based on the evaluation of one or more criteria [9].

Previously, in research [10], they made a thematic map of the area prone to Dengue Hemorrhagic Fever (DHF) in Pati Regency using Simple Additive Weighting (SAW) method. This research creates a description of the DHF-prone areas, but this research has not been applied to GIS. There is also a study [11], which made GIS for the classification of areas prone to pulmonary TB in West Java Province using the Fuzzy Tsukimoto Method. This study can determine the level of vulnerability of an area to pulmonary TB by using TB cases, population density, mortality, index of households with clean and healthy living habits and health facilities as variables to draw conclusions on areas prone to TB disease. For this reason, in this study, Simple Additive Weighting (SAW) method is proposed as a

decision-making method to make a map of the area with the level of contact risk factors for TB disease in Bandarlampung.

In this paper, a geographical information system will be proposed to map the spread of TB disease in each District in Bandarlampung City and provide information about areas with levels of risk factors for TB disease contact. This study uses Simple Additive Weighting (SAW) method to add weight using the distribution of TB factors, namely TB cases, population density, households with clean and healthy living habits and health facilities as weighting criteria to determine the level of risk in a District in Bandarlampung City, contact with TB disease. That way, visitors who are the general public can find out the spread of TB disease so that they can be more careful, and the Health Agency can make plans to prevent the spread of TB disease in Bandarlampung.

2. Methodology

2.1 System Architecture

GIS spread of TB disease is limited to Bandarlampung City and is used by 2 types of users, admin and visitors. An Actor called Admin is an officer of the Bandar Lampung City Health Office who have role to input data into the system, but admin can also see the Map menu. Visitors who are the public can only access the Map. This system will produce 3 map menus, the TB Patient Distribution Map menu, the Health Facility Distribution Map Menu, and the Regional Map Menu with the Level of TB Contact Risk Factors. Figure 1 shows the System Architecture.

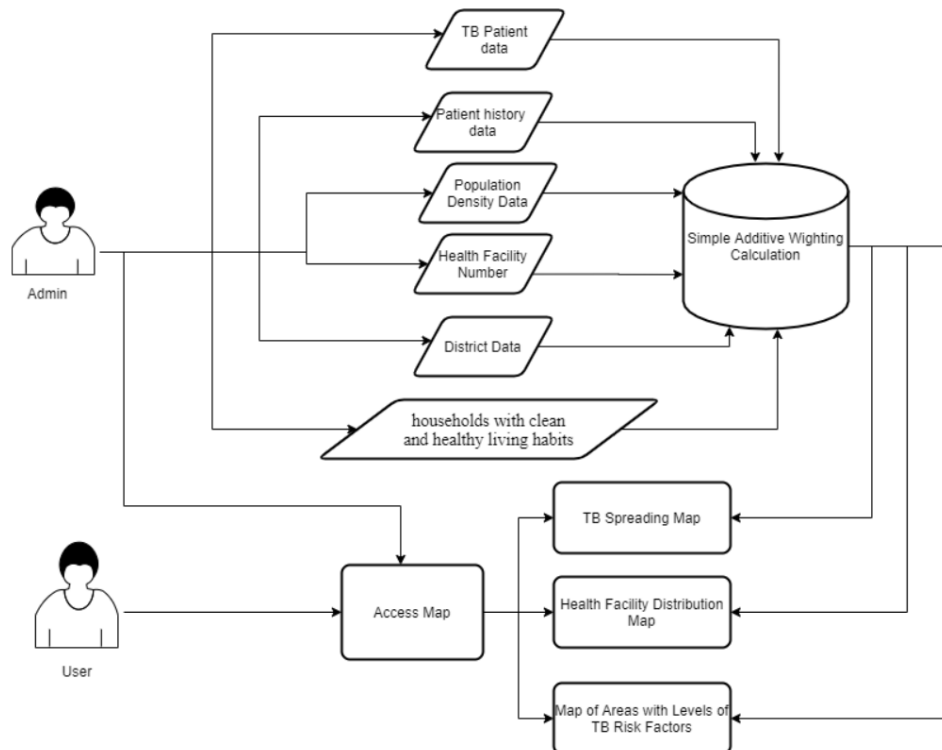


Figure 1. System Architecture

2.2 Data Source

The data used in this system include; data on the number of TB cases, the number of deaths in TB cases, health facilities and the households with clean and healthy living habits index, and health facilities was obtained from the Bandar Lampung City Health Office. Population density data were obtained from the Bandar Lampung City Statistics Agency. The data input process is carried out by the admin once every 1 month, the admin will enter new patient data, then the patient's treatment history will be updated every month for 6 months according to the TB treatment period. While the

households with clean and healthy living habits, health facilities index data, and population density data are processed every 1 year. The data used in our experiment are 2017 data.

2.3 Calculation of Simple Additive Weighting (SAW) Method

The criteria used to rank areas by the level of TB risk factors were TB cases, population density, mortality, households with clean and healthy living habits (RTPHBS) index, and health facilities. These criteria are distinguished by two categories of Cost and Benefit, with TB cases, population density, death in the Cost category, while the RTPHBS index and health facilities are included in the Benefit category. Then make weights in each criterion, range and value according to existing data. The weight of the criteria will be shown in table 1 to table 5.

Table 1. The Weight of TB cases

TB Cases (C1)	Value (Weight)
0-15	1
16-30	2
31-45	3
46-60	4
>60	5

Table 2. Population Density Weights

Population Density (C2)	Value (Weight)
1-2.500	1
2.501-5.000	2
5.001-7.500	3
7.501-10.000	4
>10.000	5

Table 3. Weight of TB Deaths

TB Deaths (C3)	Value (Weight)
0	1
1	2
2	3
3	4
>3	5

Table 4. Weight of RTPHBS index

Indeks RTPHBS (C4)	Value (Weight)
0-2.000	1
2.001-4.000	2
4.001-6.000	3
6.001-7.000	4
>7.000	5

Table 5. Weight of the Medical Facility

Medical Facility (C5)	Value (Weight)
0	1
1	2

2	3
3	4
>3	5

Then, the research data from each criterion in 20 Districts (Ai) will be weighted, then a decision matrix X will be made :

Table 6. Research Data

Name of the District (Ai)	TB Cases	Population Density	Deaths	RTPHBS	Medical Facility
Tanjungkarang Barat	25	2349	1	4288	2
Kemiling	39	3181	0	6309	5
Langkapura	14	8917	0	5130	1
Kedaton	30	12291	0	3683	2
Rajabasa	22	3921	1	4368	3
Tanjung Senang	37	6407	2	5400	1
Labuhan Ratu	25	4831	0	4886	1
Sukarame	24	3849	0	5678	5
Sukabumi	23	1235	0	6652	3
Wayhalim	27	11926	0	1902	3
Telukbetung Barat	19	4310	1	4842	1
Telut betung timur	26	3983	0	7425	2
Teluk betung selatan	26	12277	0	4638	1
Teluk betung utara	39	13740	0	5120	3
Bumi waras	64	8245	0	5520	1
panjang	54	3333	0	4930	1
Tanjung karang timur	38	24549	2	4908	1
kedamaian	26	4974	0	5203	2
Tanjung karang pusat	34	12568	0	5845	4
enggal	15	12382	2	3705	1

$$X = \begin{bmatrix} 2 & 1 & 2 & 3 & 3 \\ 3 & 2 & 1 & 4 & 5 \\ 1 & 4 & 1 & 3 & 2 \\ 2 & 5 & 1 & 2 & 3 \\ 2 & 2 & 2 & 3 & 4 \\ 1 & 3 & 3 & 3 & 2 \\ 2 & 2 & 1 & 3 & 2 \\ 1 & 2 & 1 & 3 & 5 \\ 1 & 1 & 1 & 4 & 4 \\ 2 & 5 & 1 & 1 & 4 \\ 1 & 2 & 2 & 3 & 2 \\ 2 & 2 & 1 & 5 & 3 \\ 2 & 5 & 1 & 3 & 2 \\ 3 & 5 & 1 & 3 & 4 \\ 5 & 4 & 1 & 3 & 2 \\ 4 & 2 & 1 & 3 & 2 \\ 3 & 5 & 3 & 3 & 2 \\ 2 & 2 & 1 & 3 & 3 \\ 3 & 5 & 1 & 3 & 5 \\ 1 & 5 & 3 & 2 & 2 \end{bmatrix}$$

The next step is to determine the weight of the TB criteria which will be shown in the table Weights for each criterion obtained from expert consultations or parties who have conducted TB disease research.

Table 7. Bobot Kriteria

Criteria	Description	Weight	Risk Description
C1	TB Cases	45%	Very Influential
C2	Population Density	30%	Very Influential
C3	Deaths	5%	Quite Influential
C4	RTPHBS	10%	Influential
C5	Medical Facility	10%	Influential

The next step is to normalize the X matrix to calculate the value of each criterion according to the cost and benefit category with the formula:

$$r_{ij} = \begin{cases} \frac{x_{ij}}{\text{Max}_i x_{ij}} & \text{if } j \text{ is benefit attribute (benefit)} \\ \frac{\text{Min}_i x_{ij}}{x_{ij}} & \text{if } j \text{ is cost attribute (cost)} \end{cases} \tag{1}$$

The following will give an example of normalization calculations to find the values of r11 and r14.

- The number of TB cases criteria, including benefit.

$$r_{11} = \frac{2}{\text{Max} \{2;3;1;2;2;1;2;1;1;2;1;2;2;3;5;4;3;2;3;1\}} = \frac{2}{5} = 0,40$$

- RTPHBS index, including cost.

$$r_{14} = \frac{\text{Min}\{3;4;3;2;3;3;3;4;1;3;5;3;3;3;3;2\}}{3} = \frac{1}{3} = 0,33$$

from the results of these calculations, the normalized matrix R is obtained,

$$R = \begin{bmatrix} 0,40 & 0,20 & 0,67 & 0,33 & 0,67 \\ 0,60 & 0,40 & 0,33 & 0,25 & 0,40 \\ 0,20 & 0,80 & 0,33 & 0,33 & 1,00 \\ 0,40 & 1,00 & 0,33 & 0,50 & 0,67 \\ 0,40 & 0,40 & 0,67 & 0,33 & 0,50 \\ 0,20 & 0,60 & 1,00 & 0,33 & 1,00 \\ 0,40 & 0,40 & 0,33 & 0,33 & 1,00 \\ 0,20 & 0,40 & 0,33 & 0,33 & 0,40 \\ 0,20 & 0,20 & 0,33 & 0,25 & 0,50 \\ 0,40 & 1,00 & 0,33 & 1,00 & 0,50 \\ 0,20 & 0,40 & 0,67 & 0,33 & 1,00 \\ 0,40 & 0,40 & 0,33 & 0,20 & 0,67 \\ 0,40 & 1,00 & 0,33 & 0,33 & 1,00 \\ 0,60 & 1,00 & 0,33 & 0,33 & 0,50 \\ 1,00 & 0,80 & 0,33 & 0,33 & 1,00 \\ 0,80 & 0,40 & 0,33 & 0,33 & 1,00 \\ 0,60 & 1,00 & 0,33 & 0,33 & 1,00 \\ 1,00 & 0,40 & 1,00 & 0,33 & 0,67 \\ 0,80 & 1,00 & 0,33 & 0,33 & 0,40 \\ 0,60 & 1,00 & 1,00 & 0,50 & 1,00 \end{bmatrix}$$

The next step is the ranking process, by calculating the normalized value of R multiplied by the weight of the criteria. Some example of the calculation as follows.


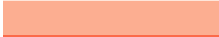


$$V1 = (0,40 \times 45) + (0,20 \times 30) + (0,67 \times 5) + (0,33 \times 10) + (0,67 \times 20) = 37,35$$

$$V2 = (0,60 \times 45) + (0,40 \times 30) + (0,33 \times 5) + (0,25 \times 10) + (0,40 \times 20) = 47,15$$

$$V3 = (0,20 \times 45) + (0,80 \times 30) + (0,33 \times 5) + (0,33 \times 10) + (1 \times 10) = 47,95$$

After the calculation results are obtained, then ranking is carried out by making a quartile range by the system where the range is divided into 4 levels of ranking status which can be seen in table 8.

Table 8. Range status

Value	Status	Color
24,15-41,32	Low Contact Risk	
41,33-47,54	Medium Contact Risk	
47,55-63,37	High Contact Risk	
63,38-83,95	Very High Contact Risk	

3. Result

3.1 Discussion

The results of this study are web-based GIS for the spread of TB disease in Bandar Lampung City with the results of visualizing the spread of TB disease and areas with the level of TB contact risk factors from the calculation of SAW method into a map. This system is created using PHP and MYSQL programming as the system database. There are three map menus in this system which are displayed in a monthly period.

3.1.1 Distribution Map of TB Patients

This map menu displays a map of the distribution of TB patients based on their address in Bandar Lampung city in the selected month and year. User can also see the distribution of patients per districts by selecting sub-district options. The page view of the distribution map of TB patients can be seen in Figure 2.

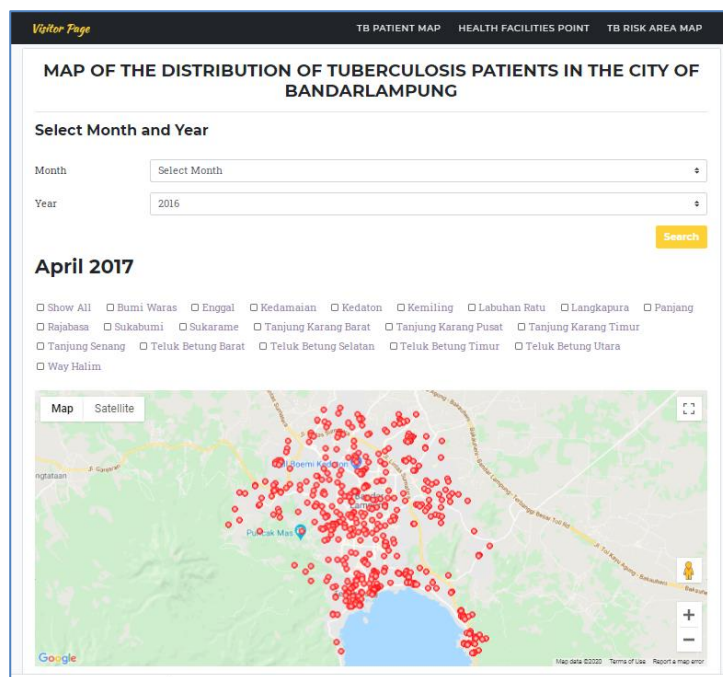


Figure 2. Distribution Map of TB Patients

3.1.2 Health Facility Distribution Map

This map menu displays point distribution map of health facilities that handle TB cases in Bandar Lampung city in the selected month and year. Information about names, addresses, and number of patients treated also was displayed when user click the point. The page view of the distribution map of TB patients can be seen in Figure 3.

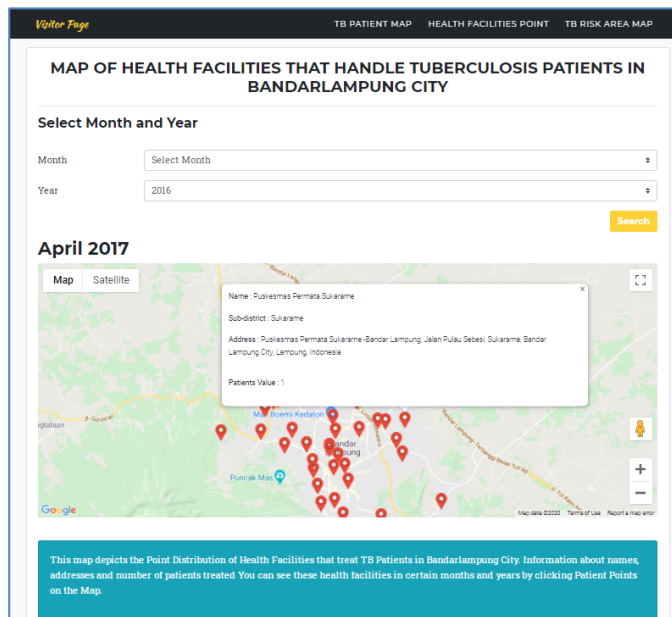


Figure 3. Health Facility Distribution Map

3.1.3 Area Map with Level of TB Contact Risk Factors

This page displays a map of the District area with the TB Contact Risk Factor Level in Bandar Lampung city, the area map is displayed in the form of colored polygon. The map color depicts the level of risk factors taken from the calculation results of the decision-making system using Simple Additive Weighting (SAW) method. The darker of the colour show higher risk for the area. View of the Map of the Area with the TB Risk Factor Level can be seen in Figure 4.

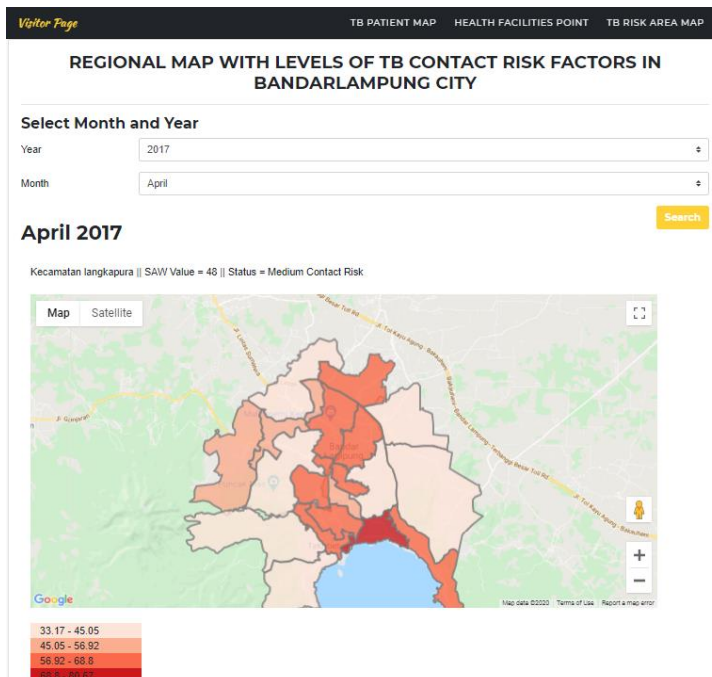


Figure 4. Area Map with Level of TB Contact Risk Factors

3.2 Testing

Software testing was carried out on GIS for the spread of TB disease by the black box testing method. The tests carried out include functional and non-functional testing involving respondents as system testers.

3.2.1 Functional Testing

Functional testing is carried out by system users, in this research, admin is from Bandar Lampung City Health Office staff. This step was taken to ensure that the functions in the system can run as expected. Examples of functional test results can be seen in Table 9.

Table 9. Functional Test Results

No.	Test Class	Test List	Test Class	Expected Results	Actual Results
1.	Health Facility Distribution Map Page	Test on displaying a map of the distribution of health facility.	Select the health facility distribution map on the header.	Displays the year and month search box at the health facility that the user might want to see.	Successfully displays the Year and Month search boxes.
		Tests on the search for the year and month of the health facility map that the user might want to see.	Choose year and month then click "Search"	Displays the map of the distribution of health facilities that handle TB disease in Bandar Lampung city.	Successfully displaying the distribution map of health facilities according to the selected month and year.

3.2.2 Non-functional Testing

Non-functional testing conducted in this research focuses on assessing aspects of ease of use and understanding the system (user friendly). This test was done by distributing a number of questions related to the system in the form of a questionnaire to 30 respondents as users of the system. Every question given can be responded to using the following Likert criteria :

1. Strongly Agree (5)
2. Agree (4)
3. Neutral (3)
4. Disagree (2)
5. Strongly Disagree (1)

The number of non-functional test scores that have been multiplied by the Likert criterion weight is shown in Table 10.

Table 10. Non-Functional Testing Table

No.	Question	Score					Score Total
		SA	A	N	D	SD	
		5	4	3	2	1	
1	GIS Spread of TB disease is easy to operate.	16	14	0	0	0	136
2	Easy to understand the system.	11	17	2	0	0	129

3	The GIS appearance of the Spread of TB Disease is appropriate.	6	23	1	0	0	125
4	GIS of the spread of TB disease provides accurate information.	7	17	6	0	0	121
5	GIS of the spread of TB disease provides information as desired.	5	18	7	0	0	118
6	The results of regional decisions with the level of TB contact risk factors are appropriate.	4	22	4	0	0	120
7	Colour and display on this system is appropriate.	12	14	4	0	0	128
8	GIS Spread of TB disease can fulfill user needs.	7	19	4	0	0	123
9	The menu on the GIS of TB disease is easy to understand.	17	10	3	0	0	137

The results of the questionnaire answers were analyzed using the Likert scale calculation at certain intervals. The results of the Likert scale equation show the scale range of each specification of the respondent category of each user. Here is the formula for calculating the scoring interval for each question :

$$I = \frac{100\%}{\text{many categories}} = \frac{100\%}{5} = 20\% \tag{2}$$

Based on the interval calculation formula, the value of 20% is obtained as the interval from the Likert scale criteria. So that the scale range for each category of the respondent's assessment is as follows:

- 1. score 1% - 20% = Very Poor,
- 2. score 21% - 40% = Poor,
- 3. score 41% - 60% = Acceptable,
- 4. score 61% - 80% = Good,
- 5. score 81% - 100% = Very Good.

Meanwhile, to find out the number of answers by percentage, the following formula is used.

$$P = \frac{xi}{n*N} x 100\% \tag{3}$$

Based on this formula, P is the percentage, xi is the total score for each questionnaire answer, n is the number of respondents (30), and N is the number of likerts used (5). From this formula, the percentage of each total score of the assessment criteria is calculated, for example the percentage calculation of the criteria for question number 1 with a total score of 136.

$$P = \frac{136}{30*5} x 100\% = 90,67 \%$$

After the total percentage in each criterion is calculated, the average result of all percentages is 84.00%, this score is in the "Very Good" category. Based on the assessment criteria in non-functional testing, it can be concluded that the system built is included in the "Very Good" category.

4. Conclusion

In this research, it can be seen that GIS can be used very well in the field of public health. The results of data processing are visualized in graphic form in the form of maps, making it easier for users to

read data on the spread of TB disease in Bandarlampung. The use of SAW method decision-making system that produces regional decisions with the level of TB risk factors can be taken into consideration by the Bandarlampung City Health Office to take preventive actions in areas with very high and high risk levels. Based on non-functional testing by 30 respondents, this system falls into the "very good" category.

The suggestion that can be given is the presentation of a menu of TB distribution maps, health facilities, and areas with a TB risk level to be presented every 6 months so that data changes can be seen. Then, features that can connect TB patients and the system will be added, so that the system can notify patients of treatment time, and update all the data to synchronize information change.

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