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Measuring spatial accessibility of healthcare services using ARIA method, case study at Bandar Lampung City

To cite this article: A Hijriani and R I Putra 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **739** 012094

Measuring spatial accessibility of healthcare services using ARIA method, case study at Bandar Lampung City

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Abstract. Accessibility of health services in Indonesia is still a problem. Health equity focuses on easy access and equitable distribution of health services and obtaining services with a standard quality set. Three dimensions of in-depth equity health can be divided into equity in health status, equity in health service use, and equity in health financing. The entire population is a health insurance participant. Health services that benefit packages include comprehensive services (preventive, promotive, curative, and rehabilitative). Government-owned health facilities must be provided, such as community health centers, clinics, doctors, hospitals, and financing paid by the government; the people who can afford it pay a premium. In this study, the accessibility of health services at hospitals and health centers in the city of Bandar Lampung was analyzed in geographic references by determining the distance and ranking health facilities ranging from very high to less accessibility value categories using the ARIA accessibility index calculation method. For hospital accessibility, Panjang district had the lowest index. Meanwhile, this district had a very high index for community health center accessibility compared to others. In health clinic accessibility, Teluk Betung Barat District had the lowest index, and Tanjung Karang Barat District had the highest index.

1. Introduction

Geographic Information Systems (GIS) is a system that collects, store, manage, manipulate, and analyze information based on location or spatially referenced on the earth. This geospatial data will be transformed into many formats to support the decision-making process or show information and guide people to a specific location. Sometimes, the process that generates the information from GIS can interfere by many factors, including political, economic, and social motivations. This process needs more interpretation and further research to produce new policy or government decisions [1], [2].

Generally, spatial data is based on a map containing interpretations and projections of all phenomena on earth. Following developments, the map does not only represent objects on the earth. Still, it develops into a representation of objects above the earth's surface (in the air) and below the earth's surface. GIS implementation could be in many fields, agriculture, politics, economy, or even public health. In the public health area, the availability of health service facility case is important to carry out health service efforts, either promotive, preventive, curative, or rehabilitative facilities. It can be the responsibility of the government, regional government, and the community.

Since the number of health care centers, clinics, and hospitals increases rapidly, this also applies to the cost of the services. There are also demands to reduce costs and more pressure to improve service, patient safety, reduce patient waiting times, minimize errors and associated legal action. The total time of the service from the patient registration to all patient treatment needs to be improved. [3]. Health Policy from the government should consider the location and infrastructure budget. The

distance from the residential area factors has the same needs that the facilities should be easy to access and prevent the possibility of the spread of infectious disease.

In 2013, Bandar Lampung's city saw the sub-districts' division from 13 to 20 sub-districts and villages from 98 to 126. Health facilities in Bandar Lampung City, amounting to 20 hospitals, consisting of 10 Special Hospitals, 4 Government Hospitals and 6 Hospitals Private Hospitals, 21 Health Centers, and 55 Clinics, which must serve approximately 979,287 people in Bandar Lampung City [4].

Several studies have been conducted to determine the level of access to health facilities. Research from [5],[6] consider distance and population in a particular area and looking for a suitable new location if new health facilities are needed. The research from [7], [8] using Euclidian distance and driving time to calculate hospital coverage service. In the study conducted by [9], the Gravity Method method, the most famous synthesis model (spatial interaction) assumes that the generated and attractive movement characteristics are related to several origin zone parameters, such as population. This method uses the time and distance traveled as its measurement parameters. The Department of Health developed the other way at the University of Adelaide to determine the hospital accessibility index to Australia's remote areas. This method named the Accessibility Remoteness Index of Australia (ARIA). This method is simple and can be used to determine the index of accessibility to health facilities in an area not only in Australia [10], [11], [12].

This research will use web services from Google that have open services for the benefit of data integration and information collaboration that can be accessed via the internet by various parties using technology owned by each user. The website will be developed as a collection of pages that can be accessed or viewed over the internet and display the information based on spatial analysis for health facilities location [13], [14].

In this study, the accessibility of health services at hospitals and health centers in the city of Bandar Lampung was analyzed in geographic references by determining the distance and ranking health facilities ranging from very high to less accessibility value categories using the ARIA accessibility index calculation method. Hopefully, this information system will provide accurate, timely, and relevant information to users to be used for decision making.

2. Methods

2.1 System Architecture

The system is used by two types of users, admin and visitors. An actor called admin is an officer of the Bandar Lampung City Health Office who has the role to input data into the system, but the admin can also see the Map menu. Visitors who are the public can only access the map. Figure 1 shows the use case diagram for the system.

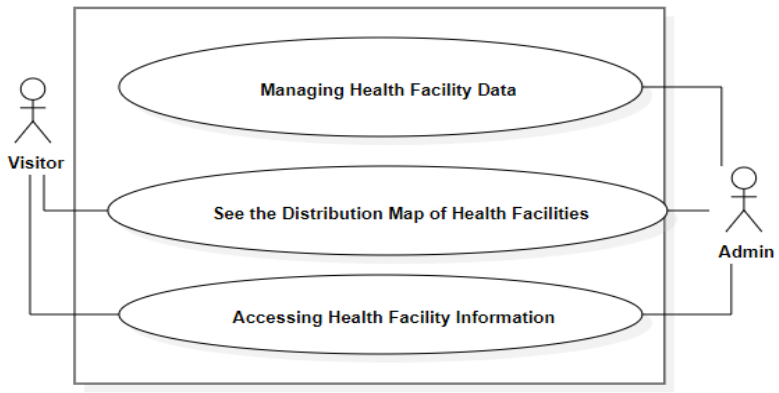

Figure 1. Use Case Diagram

2.2 Data Source

Data collection methods can be divided into two types, primary and secondary data. Primary data were obtained from interviews with the Bandar Lampung City Health Office in the Health Service Sector and, at the same time requesting health facilities data. Secondary data is obtained from books,

journals, and the internet, which provide information about GIS, Google Maps API, and the accessibility Index.

2.3 Research Stages

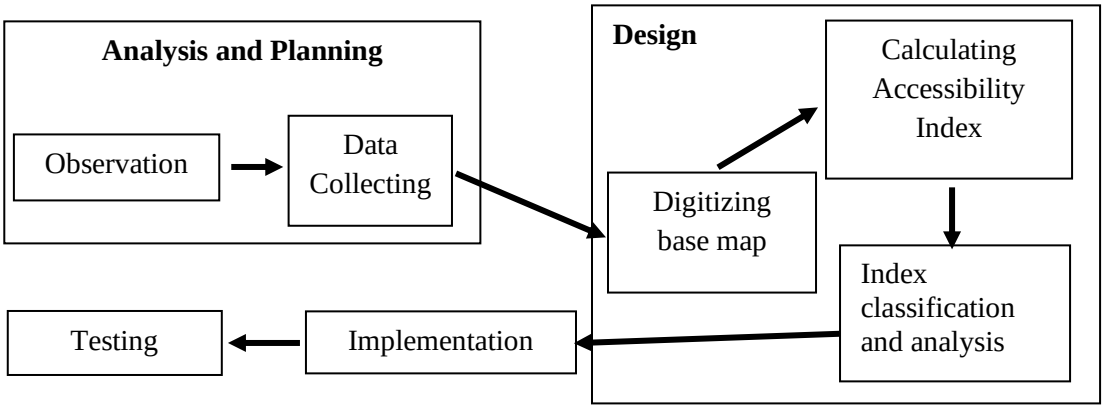

Figure 2. Research Stages

In developing an information system, preparation and planning are needed, where data is required to support the development of an information system. The method used in the data collection stage is a literature study, observation, and interviews. Observations in this study were carried out before the preprocessing, which was useful for obtaining information. Information that would then be collected and then used to make a base map.

This research was conducted based on the stages depicted in Figure 2. Data was collected from various sources such as health agency websites and digital maps such as Google Maps or Open Street Maps in the first stage. Data on the city of Bandar Lampung's administrative boundaries is needed to make a basic map and data on health facilities and address information. The collected data on health facilities are grouped into three hospitals, community health centers, and clinics.

Basic map processed using Quantum GIS software by creating polygon for each district in Bandar Lampung City and compare the result with the administrative boundaries set by the Bandar Lampung City Government. The next step overlays the location of health facilities and roads, partitioning the grid area, partitioning the area based on sub-districts, and creating a centroid for each grid and sub-district area.

The accessibility index calculation uses the ARIA method (GISCA 2001) and the index class division method uses the method was carried out in several stages as follows.

1. Calculate the distance per centroid to each health facility.
2. Grouping the calculation results by a group of health facilities, then finding the minimum distance of each centroid to the health facility and determining the average minimum distance from each centroid to the group's health facility.
3. The index calculation for each health facility group uses Equation 1 and determines the index range by calculating the intervals using Equation 2.

$$\boldsymbol{aij} = \frac{\boldsymbol{dij}}{\boldsymbol{dj}}$$

Equation 1, with:
aij = Area accessibility index
dij = Shortest distance from centroid i to health facility j; min (d_{ia}, .., d_{in})
dj = Average distance to health facilities j

$$\boldsymbol{x} = \frac{\boldsymbol{a_{max}} - \boldsymbol{a_{min}}}{\boldsymbol{class}}$$

Equation 2, with
a_{max} = Largest accessibility index to health facilities j
a_{min} = Smallest accessibility index to health facilities j
x = range of accessibility levels
class = accessibility class to define the range and number of colors

Divide the accessibility class based on the calculation of the accessibility index range in the previous step. The index class categories used based on ARIA are as follows.

a. Very High is a relatively unrestricted level of access to various goods, services, and social interactions.
b. High is the access level, which has several limitations in access to some goods, services, and social interactions.
c. Medium is the level of limited access to obtaining various goods, services, and social interactions.
d. Low is the level of access that is very limited in obtaining various goods, services, and social interactions.

At this stage, the classification is carried out according to each class's range value that has been determined in the previous stage. The results of index classification were analyzed based on each group of health facilities. The calculation of the area is based on the accessibility class for each group of health facilities. Table 1 shows the class and color for each index.

Table 1. Class status

Class	Color
Low	
Medium	
High	
Very High	

Google Maps API was used to implement the calculation of the distance for each community health center, hospital, and clinic to each district's centroid. The result will adjust the color of each polygon of the district based on the index and color.

3. Results and Discussion

3.1 Results

Web-based geographical information system accessibility of health facilities in Bandar Lampung City is a system built to represent the accessibility of health facilities in the Bandar Lampung City area. The results can be considered in decisions to construct further health facilities. The web application using PHP, HTML, and Javascript as web programming languages.

The process of making a base map uses the coordinates obtained from the website. The coordinates of the existing centroids are obtained from existing Quantum GIS tools and are then taken to be the starting point for the calculated distance. The process of making a base map by creating a polygon layer according to the map's line boundaries, resulting in a base map like the following figure 3.

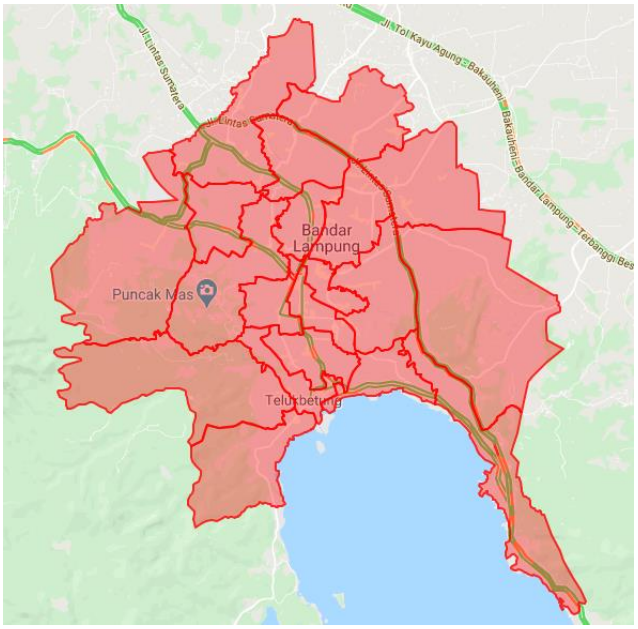

Figure 3. The result of digitizing base map

Overlay of health facilities is done by collecting the coordinates of each health facility. What is done at this stage is adding a layering point according to the health facility's location to produce a map like Figure 4.

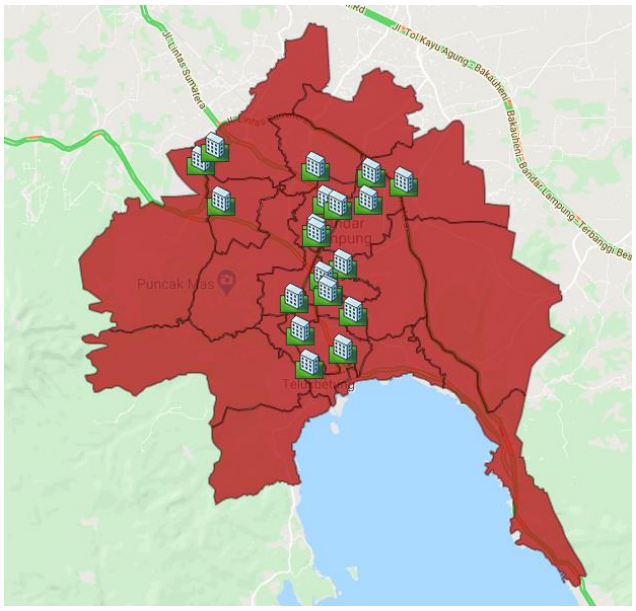

Figure 4. Health Facility Distribution Map

The process of calculating the accessibility index is carried out in various stages so as to produce an index for the area and range at each level. The steps to obtain the index are carried out using Equation 1. It uses the closest distance from an area to the health facility obtained, then obtaining the average of each distance, then dividing the closest distance by the average. In Equation 2, we have obtained the smallest and largest indexes, then by reducing the largest index from the smallest, then dividing by the color class, in this case, is four (4). It has been obtained from the smallest to the largest ranges for

classifying regions into gradient colored polygons. Table 2 shows the health facilities group, accessibility class, and index range.

Table 2. Health facilities group, accessibility class, and index range

Health Facilities	Accessibility Class	Index Range
Hospital	Low	2.633604619 – 3.461893116
	Medium	1.805316121 – 2.633604619
	High	0.977027623 – 1.805316121
	Very High	0.148739125 – 0.977027623
Health Center	Low	2.439557909 – 3.166935298
	Medium	1.712180520 – 2.439557909
	High	0.984803131 – 1.712180520
	Very High	0.257425743 – 0.984803131
Clinic	Low	2.581945191 - 3.406233208
	Medium	1.757657174 - 2.581945191
	High	0.933369156 - 1.757657174
	Very High	0.109081139 - 0.933369156

The hospital health facilities group obtain the results of the calculation of the minimum index value of 0.148739125 and the maximum index value of 3.461893116. For the Public Health Facilities group, the minimum index value calculation is 0.257425743, and the maximum index value is 3.166935298. The next step is to classify each polygon region's index based on the class that has been divided and according to the quarter. The result of color classification is that the darker the color on the polygon, the lower the level of access, conversely the lighter the color on the polygon, the higher the level of access. Areas that have a high index will be justified as having a low level of access. The visualization of the index color is can be seen in Figure 5.

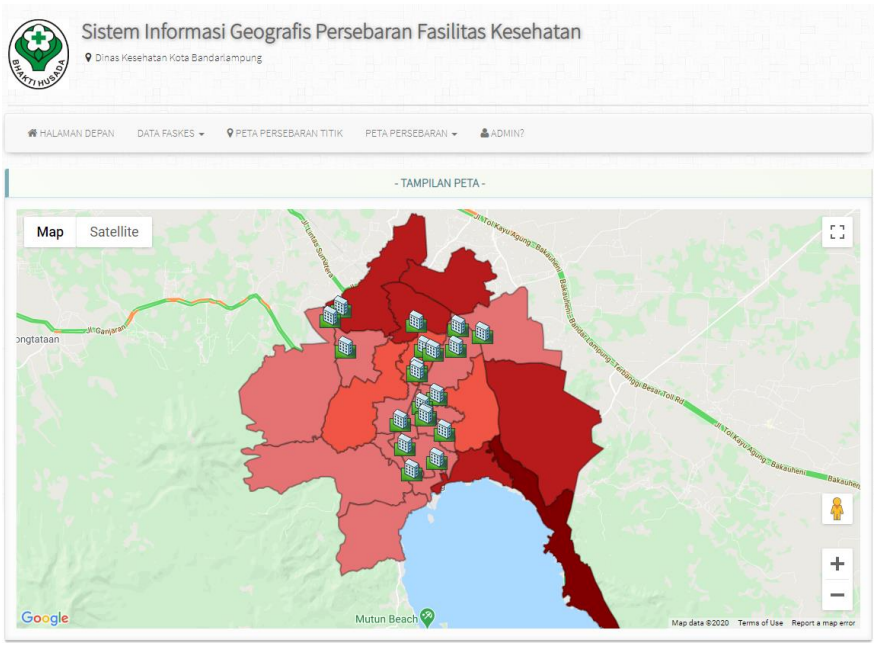

Figure 5. Visualization Module

After all the output was displayed successfully, software testing was carried out by the black box testing method. The tests carried out include functional testing by health office staff of Bandar Lampung City on October 17th, 2020. This step was taken to ensure that the functions in the system can run as expected. The test case that had been tested displayed in Table 3.

Table 3. Functional Test Results

No.	Test Class	Test List	Test Class	Expected Results	Actual Results
1.	Manage Health Facilities Data	Change the available health facilities data	Fill in the health facility name form field	The system successfully changes data and displays health facilities data	The system successfully stores data and displays health facilities data
			Clear the health facility form fields	The system makes denial	The data was not saved successfully, and the system displays a reject message
		Delete and Add the available health facilities data	Pressing the delete button and add button	The system will delete health facility data and add health facility data.	The system deletes data and displays a message that the data has been deleted System add new location of health facilitied data
2.	Distribution of Health Facilities	Displays the point of location of Health facilities	Pressing the distribution menu of health facilities	The distribution page of health facilities will display the points of location of health facilities	The system displays points of location of Health facilities on the distribution page of Health facilities

This software test gets the results as appropriate. This website displays the point of health facilities and polygon colors in accordance with the index and can also change and manage the data of health facilities in Bandar Lampung city.

3.2 Discussion

Accessibility to health facilities require many factors to be considered, in simple way, it means people is able to get the health services when they are need it. Using GIS also can see the pattern about information location, type of the services or resources. There was many research doing different approach such as: (a) calculate the distance in spherical form between two different location; (b) using Euclidian distance, to measure straight-line between two points; (c) using grid of the area and calculate Manhattan metric; and (d) using road as line network to calculate the distance. This research using the last approach that connect each centroid of district in Bandar Lampung City to preferred health facilities category. Figure 6 shows the classification for each category.

Figure 6.a shows that hospitals are not spatially distributed in all area of Bandar Lampung City. Most of the hospitals were located around the city center. People who live in Panjang District had the lowest accessibility index than Enggal district, with the highest accessibility index. The other districts that have low accessibility index are Sukabumi, Bumi Waras, Tanjung Senang, Labuhan Ratu, and Rajabasa districts.

The opposite results can be seen in Figure 6.b; for the community health center category, Panjang district had the highest accessibility index. The location of the community health center is also scattered in all areas. Most of the districts in the category had close color range except Teluk Betung Barat district.

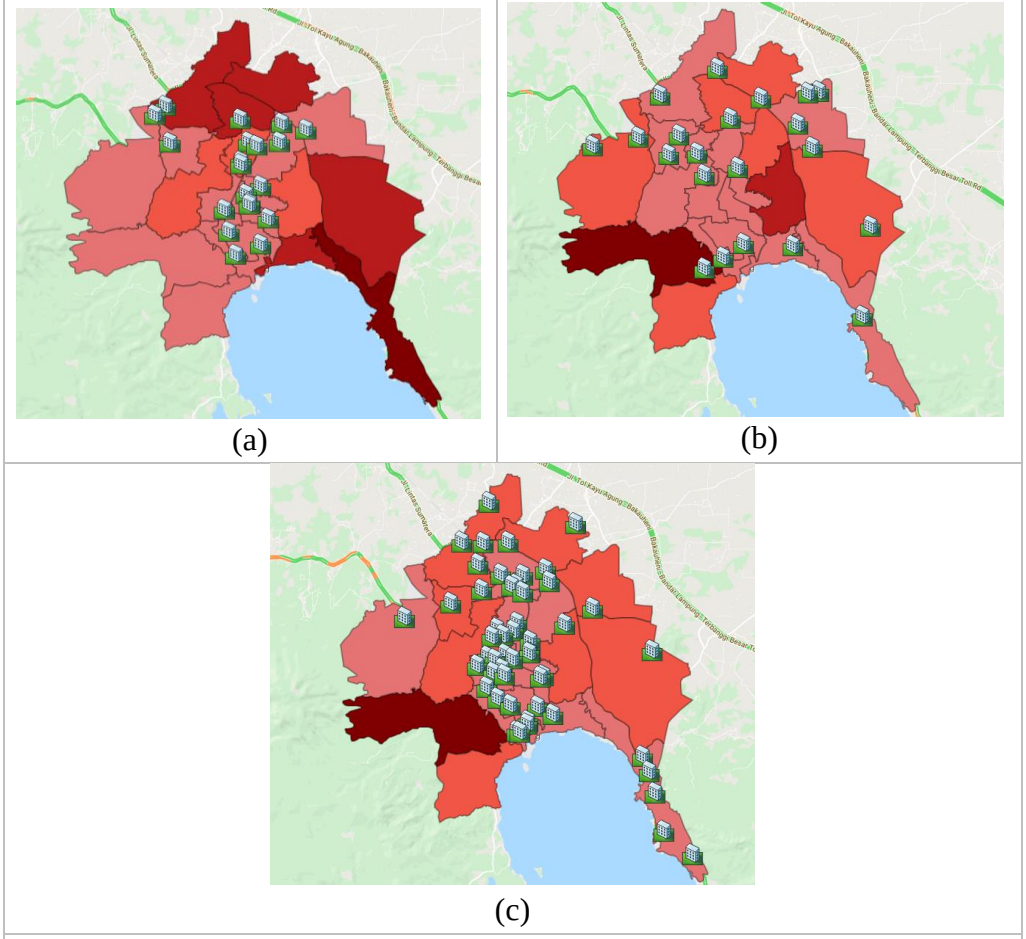

Figure 6. Classification of Health Facilities for each District (a) Hospitals, (b) Community Health Center, (c) Clinic

For the clinic category in Figure 6.c, Teluk Betung Barat District also had the lowest index. Since the clinic's distribution is grouped around the main road, Tanjung Karang Pusat district had the highest accessibility index. In this category, Panjang district also had a very high accessibility index because some companies in Panjang area build clinics that can serve the staff and people who live around it.

4. Conclusion

From the results obtained from this study, there are several districts with no hospitals, but they have other community health centers and clinics such as Panjang District. Teluk Betung Barat district is an example of a district with little accessibility to community health centers and clinics, but it closes to one local hospital. The people who live in the center of the city have more access to all health facilities. Enggal district had very high access to the hospital, and Tanjung Karang Pusat district had very high access to the clinic.

Based on the analysis, design, and implementation of the system carried out, several suggestions need to be considered in developing this system, adding the travel time and health facilities opening time as parameters for the accessibility index, calibrating the actual distance to the health facility and improvise the display interface. This accessibility measurement will also be more useful for other areas with wide areas and diverse population distributions. The information generated can later be used as a basis for local governments for better health services.

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