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Implementation of Haversine Formula to Determine the Shortest Path Using Web Based Application for a Case Study of High School Zoning in Depok

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Abstract: The zoning system that regulates regional zones for new students is basically carried out to bring the student's domicile closer to school, the application of the zoning system is carried out at every level by the Regional Government in accordance with its authority. In the application of zoning system, it is necessary to pay attention on the availability of the school capacity which is adjusted to the availability of the number of school-age children at each level in the area. Depok only has 13 Public Senior High School spread across 11 sub-district which can accommodates 3,858 Junior High School graduates. This becomes disproportionate to the number of junior high school graduates which are more than the school available capacity. The condition that occurs is that there is no form of calculating the distance from student's location to the school based on a straight line so that an accurate distance is obtained. In this study, a mapping of the distribution of high school in Depok was carried out, then the distance was calculated using the Haversine formula. Implementation of distance measurement in this study in the form of a website. The results of the study can provide distance information to get school recommendations that are in accordance with the zone criteria, and this study has a good accuracy value of 97.22%.

Keywords: Depok, Formula, Haversine, Zoning, Website

1. Introduction

Technology that is developing very quickly makes people must be able to adapt to current technology, several applications that support school information services have been widely used, ranging from registration applications and there are various applications used for learning and examinations for students. This application provides convenience for users and provides transparency and clarity of stages and results. The zone-based school registration is a form of selection stage based on the proximity of student's location to school, so that students can get a school that is near to their home location. Basically, the zoning system is carried out to bring the student's domicile closer to the school. The determination of zoning is carried out at every level by the Regional Government in accordance with its authority. In the application of zoning, it is important to pay attention on the amount of school available capacity according to the availability of the number of school-age children at each level in the area. A written agreement between local government is carried out in determining the zone at each school level located in the provincial or district/city border areas.

New student admissions using the zone system have been going on since 2017 in Depok area, then in 2020 a zoning rule was developed based on the mayor's regulation no. 20 of 2020 that the nearest location to school is seen based on the address on the latest Family Registration Card at least one year before student admission [1].

In the 2020 New Students Admission, West Java Education Office opened four New Students Admission lines for the high school level which were divided into two stages. The first stage has 3 pathways, the first path is the 20% affirmation path

consisting of 18% Economic Poor Families and 2% Covid-19 medical personnel. The second path is the 25% achievement path which consists of 20% report card achievement and 5% championship achievement and the last is the 5% parental transfer path. In the second stage, the zoning path with a quota of 50% is used. Depok only has 13 Public High Schools spread over 11 sub-districts which can accommodates 3,858 Junior High School graduates. This becomes disproportionate to the number of Junior High School graduates which are more than the school available capacity [2].

The use of technology that utilizes Geographic Information Systems (GIS) functions to collect, manage, store and present data related to the geographical conditions of an area [3]. In this study, 13 high school data were used in the LapFasDik database in West Java. The school data is contained in the form of a distribution map which is made through a digitization process and data from coordinates of the Global Positioning System (GPS).

Global Positioning System or commonly called Location Based Services (LBS) is a location-based service or a general term that is often used to describe the technology used to locate the user's device. This service uses Global Positioning Service (GPS) technology and cell-based location from Google. LBS consists of several components including mobile devices, communication network, position component, and service and content providers. Position component in question is the position of the user must be determined. This position can be obtained by telecommunication network or by GPS, while service and content provider is a service provider that provides different services to users such as route finding, position calculation, and others [4].

Based on this technology, the distance from the initial coordinate point which is student's house to the end point, which is the school coordinates will be calculated, this is one of the objectives of this study. The resulting distance calculation can be used to determine the nearest school to student's house, so a system that is able to calculate the straight-line distance from the coordinates of student's house to the school is made, so that information is obtained which school is nearest. The haversine formula is a method that can provide answers to problems in this study. This formula is a form of equation that gives the value of the radius size between points on earth's surface in the form of longitude and latitude. The use of the haversine formula is used as an alternative to the right formula for calculating distances at two coordinate points based on the latitude and longitude values given as initial coordinates and final coordinates. The nearest distance and school identity are generated as an external form [5]. This study can also direct students to their preferred school in a fast and easy way. The system used to find the distance between the location of student's house to the school uses the haversine formula [6].

The implementation of the Haversine formula in this study is a web-based application that provides a coordinate determination service based on the domicile of students then connected to the coordinates of each school in the Depok area, the output given is the distance calculation result based on the smallest value which is the nearest distance from student's home location.

2. Literature Review

2.1. Geographic Information System (GIS)

Geographic Information System is a combination of three words, namely system, information, and Geographic, from these three words it can be said that a Geographic Information System (GIS) is the use of a system containing information about the condition of earth from a spatial point of view. GIS is a special system that is used to process databases that contain geographic reference data and contain spatial information [7].

Geographic Information System is formed by five elements that are interrelated with each other, including hardware which is a supporting equipment for system work such as CPU, monitor, digitizer which have different functions. The next element is the software used to input or as a work program such as ArcView and ArcGIS. Data is a GIS element that functions as spatial data with earth and spatial references which will later be processed by the user into a form of application based on a certain method [8]. The image of GIS element is shown in Figure 1.

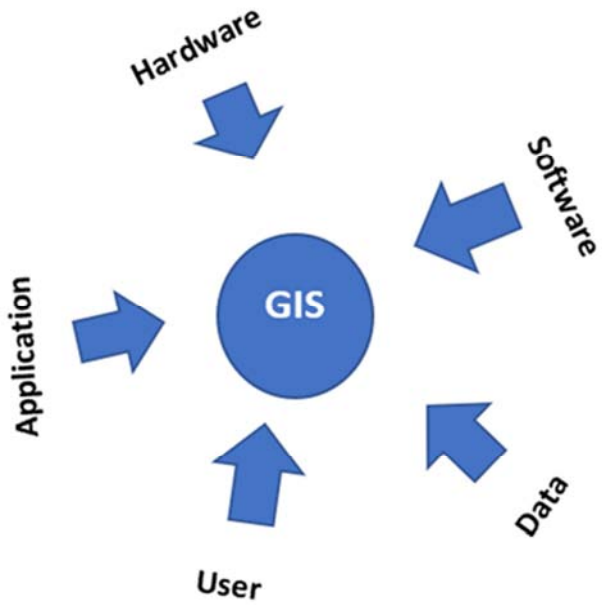

Figure 1. *Elements of Geographic Information System [8].*

2.2. Location Based Service (LBS)

Location Based Service (LBS) is a general term used to describe the technology used in finding the location of the device that is used. LBS functions as a search service using Global Positioning (GPS) technology and Google's cell-based location technology. In simple terms it can be defined that with the LBS service the user can find out the current position, the position of friends or other people, the position of the hospital, gas station or school which is the distance from the user's position. Maps and location-based services use latitude

and longitude to determine geographic location but as a user what is needed is a real time address or real time position, not latitude and longitude values.

Two elements of Location Based Service (LBS), that is:

1. Manager (API Maps): provides a tool/source for LBS, Application Programming Interface (API) Maps used as a facility that displays, manipulates maps along with other features such as satellite, street, or both the combination.
2. Location Providers (API Location): provides location search technology used by the device. API location related with GPS (Global Positioning System) data and real time location data.

2.3. Google Maps API

Google Maps API is a facility from Google that can be used to add maps to the website using programming such as JavaScript [9]. The Google Maps API provides many facilities and utilities for manipulating maps and adding content to maps through various services, such as Arc GIS. Google Maps API is used to display google maps in the form of maps on the website. A unique code called an API key is used to generate Google to Google Maps server so that it can be recognized. In addition to JavaScript, there are several other programming languages that can be used to display maps in web-based applications, including Hypertext Markup Language, Asynchronous JavaScript, and XMLHTTP [10].

2.4. Distance Measurement

Distance in this study is defined as the length of the position of an object with another object in the form of a value or numeric. The length of the distance between two objects is obtained by calculating the difference in the coordinates of the object, which is far or near. Calculating a distance in everyday life is used for example to find out the distance from two coordinates on a map. On the map the coordinate value is negative, so if the coordinates of two objects are negative then the value is considered absolute, this is because the distance must not show a negative value. The unit for calculating distances is shown in meters or kilo meters [11]. The theory of distance calculation was introduced by Euclid, with the term Euclidean distance which is calculation of the distance from two points in Euclidean space. This theory introduces the calculation of the straight-line distance (Euclid), which is to calculate the length of the shortest path between two points, which can be reached without any obstacles between the two points.

2.5. Haversine Formula

The Haversine formula is used to calculate the distance of a large circle between two coordinates on a sphere, which approximates the shape of Earth as an oblate spheroid. In fact, based on the condition of the oblate spheroid and the geometry of earth, the calculations made do not really pinpoint that point. The Haversine formula can be applied to calculate the distance in a spherical shape [12]. The distance calculation is done between two points on Earth's surface, or the sphere is measured along the surface and can be displayed on Google maps to get the shortest distance. The Haversine formula calculates the distance between initial location point and destination location point based on the length of a straight line from the latitude and longitude coordinate values obtained by the Haversine formula as follows [13]:

$$Haversine(c) = haversine\ (a - b) + \sin(a).\sin(b)\ haversine\ (C) \quad (1)$$

The haversine formula will be used in calculating the distance between two coordinate points, which is the coordinates of user's position and the coordinates of the destination point. These coordinates are latitude and longitude values, so they can be used as the primary key in the comparison of distances in determining the nearest location, with the following formula:

$$Haversine\ \left(\frac{d}{R}\right) = haversine\ (\theta_1 - \theta_2) + Cos(\theta_1).Cos(\theta_2).haversine\ (\lambda_2 - \lambda_1) \quad (2)$$

$$Haversine(\theta) = Sin^2\left(\frac{\theta}{2}\right) = \frac{1-\cos(\theta)}{2} \quad (3)$$

$\theta_1 =$ *user coordinate latitude*
$\theta_2 =$ *destination coordinate latitude*
$\lambda_1 =$ *user coordinate longitude*
$\lambda_2 =$ *destination* coordinate longitude
d = distance between 2 coordinate points
R = Earth radius (6371 Km).

3. Method

In this study, several stages were carried out to produce a smart zoning application that can be used to calculate the straight-line distance from student's domicile to school based on the calculation of the nearest distance by identifying the coordinates of the student's domicile. Next, collect the coordinates of each school so that a table of latitude and longitude coordinates is formed from 13 Senior High Schools in Depok. The next stage is to design the system by drawing the frontend and backend on the system and the architectural form used. The calculation of the distance between student's domicile to school is carried out using the Haversine formula which will produce a table of the distance and domicile of students to each school. At the final stage, the results of calculations and analysis are given from the domicile to each school and the nearest distance can be determined from the calculation, as shown in Figure 2.

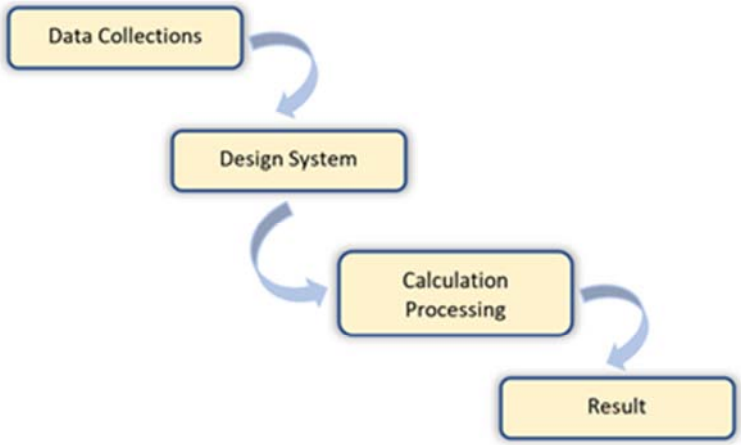

Figure 2. *Research Stages.*

Figure 3. *Coordinate Identification Algorithm [14].*

3.1. Data Collection

The activities carried out at this stage are data collection in the form of coordinates information of student's domicile and school coordinates, in this scope the Public Senior High School located in Depok. The steps taken in data collection are as follows:

A. Identification Student Domicile Coordinates

The identification of these coordinates is to determine the student's domicile coordinates. Students activate location facility on the device via a browser, then determine the address of residence, with a flow as shown in Figure 3.

B. High School Coordinate Identification

The determination of school coordinates is carried out through data collection conducted on 13 senior high schools in Depok based on LapFasDik West Java using Google Maps [15]. Furthermore, the coordinates of the school are used as information on the distribution of high schools in Depok in the form of a map. The coordinates of the school distribution points are summarized in table 1.

Table 1. *Scatter of high school coordinates [15].*

No	SMAN	NPSN	Subdistrict	Latitude	Longitude
1	SMAN 1 Depok	20223819	Pancoran Mas	-6.395047	106.814458
2	SMAN 2 Depok	20223818	Sukmajaya	-6.3946006	106.8491576
3	SMAN 3 Depok	20223817	Sukmajaya	-6.4075209	106.8409172
4	SMAN 4 Depok	20229166	Tapos	-6.394434	106.8823928
5	SMAN 5 Depok	20229167	Sawangan	-6.4011561	106.7666284
6	SMAN 6 Depok	20229168	Limo	-6.3706803	106.7733785
7	SMAN 7 Depok	20268524	Tapos	-6.3975893	106.9100008
8	SMAN 8 Depok	20270492	Cilodong	-6.424844	106.8468016
9	SMAN 9 Depok	20276187	Cinere	-6.3472217	106.7801344
10	SMAN 10 Depok	69851425	Bojongsari	-6.3932982	106.7327226
11	SMAN 11 Depok	69857937	Sukma Jaya	-6.3868742	106.8303999
12	SMAN 12 Depok	69857938	Cipayung	-6.4200047	106.794943
13	SMAN 13 Depok	69857939	Cimanggis	-6.376502	106.873379

3.2. Design System

Design process on the system consists of two parts, namely the frontend which is an interface for students by inputting data and domicile locations to get latitude and longitude coordinates. The web service that does the mapping of school coordinates and calculates the distance using the Haversine formula in the form of a query is part of the backend, as shown in Figure 4.

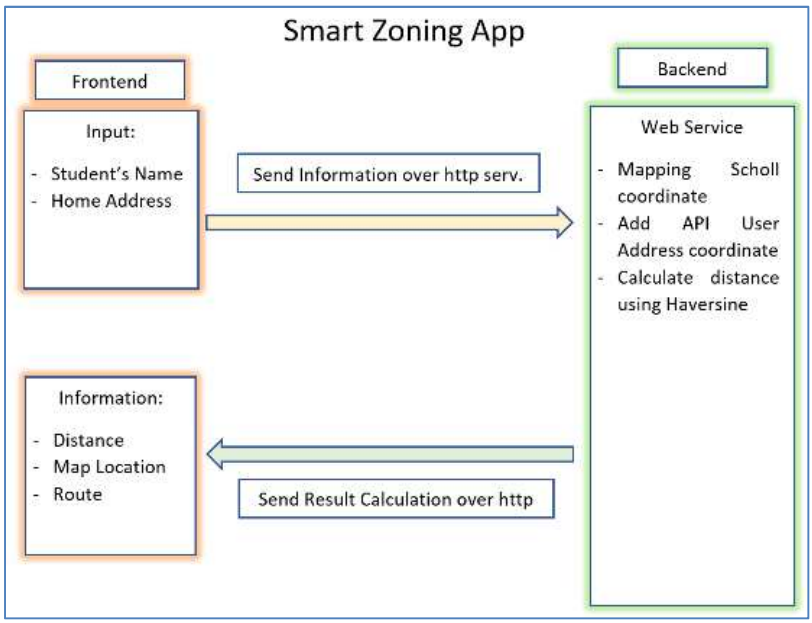

Figure 4. *Design Process System.*

Figure 5. *Architecture System.*

The system architecture in this study uses a client server-based application model that is connected via internet. Administrator can directly access the application server via a web browser to perform data updates, configuration, and maintenance. User can also access the application server through a browser to get information based on the input provided. The system architecture is shown in Figure 5.

3.3. Calculate Distance Using Haversine Formula

Measurement of the shortest distance between two points on Earth's surface is carried out along the surface, the measurement results are displayed on Google Maps. The Haversine formula calculates the distance between the coordinates of student's domicile to school's coordinates based on the length of a straight line based on longitude and latitude. The tetha symbol is the latitude value variable, which defines a straight line at a specific location on the equator. The symbol lambda as the variable longitude, defines the angle that points to the west or east of the meridian or Greenwich line. Based on the identification of the longitude and latitude values, it is continued by changing these values to radians and calculating the distance using the Haversine formula.

$$\Delta lat = \frac{\pi}{180} * (destination\ latitude - user\ position\ latitude) \quad (4)$$

$$\Delta long = \frac{\pi}{180} * (destination\ longitude - user\ postion\ logitude) \quad (5)$$

$$a = \sin(\frac{\Delta lat}{2})^2 \quad (6)$$

$$c = \cos(lat1) * \cos(lat2) * \sin\left(\frac{\Delta long}{2}\right)^2 \quad (7)$$

$$d = R * 2 * \text{asin}(\sqrt{a + c}) \quad (8)$$

Lat1 is the latitude of student's domicile location, lat2 is the latitude value of school's location. Long1 is the longitude of student's domicile location, long2 is the longitude of the school.

d = distance between 2 coordinate points

R = Earth radius (6371 km).

3.4. Calculation Result

The results of calculating the distance between student's domicile location to each school using the Haversine formula produces distance information that can be sorted based on the nearest to farthest distance, so that students get information on school recommendations based on the nearest distance from student's domicile location. The distance value is generated in kilo meters and displayed in the form of a location map, besides that additional information on the route to the destination school location is provided.

4. Result and Analysis

In this study, the Haversine formula is implemented to calculate the distance from student's domicile coordinates to school coordinates. The system will work with internet and active's location, the system will works to show the coordinates of the location by google maps. Testing the distance calculation using the Haversine algorithm is carried out by defining the latitude and longitude of the coordinates of student's domicile and coordinates of the schools. The implementation of this system was carried out on 13 Senior High Schools spread across Depok. Students can find out the distance between each school and the domicile location and get information about the distance to the nearest school from students.

4.1. Trial of Distance Calculation of Student's Domicile Locations with Each School Using the Haversine Formula

The calculation trial was carried out on 13 schools spread across Depok, in this study the calculation of thirteen schools is shown to describe the workings of the Haversine algorithm, as follows:

The coordinates of student's domicile location (user) with a latitude of -6.344740 (lat1) and longitude 106.845745 (long1), the address of residence is on Jalan Bhineka IV, Pasir Gunung Selatan, Cimanggis.

The distance calculation is carried out using the Haversine algorithm to determine the distance of a straight line to 13 Public Senior High Schools, with calculations using equations (4) to (8) as follows:

School distance calculation 1:

SMAN 1: lat2 -6.395047 and long2 106.814458

$$\Delta lat = \frac{\pi}{180} * (lat2 - lat1)$$

$$= \frac{3.14}{180} * (-6.395047 - (-6.344740)) = 0.000878$$

$$\Delta long = \frac{\pi}{180} * (long2 - long1)$$

$$= \frac{3.14}{180} * (106.814458 - 106.845745) = 0.00055$$

$$a = \sin(\frac{\Delta lat}{2})^2 = a = \sin(0.000878)^2 = 1.92536E\text{-}07$$

$$c = \cos(lat1) * \cos(lat2) * \sin\left(\frac{\Delta long}{2}\right)^2$$

$$= \cos(-6.344740) * \cos(-6.3950447) * \sin\left(\frac{0.00055}{2}\right)^2$$

= 7.40047E-08

$$d = R * 2 * \text{asin}(\sqrt{a + c})$$

$$= 6371 * 2 * \text{asin}(\sqrt{1.92536\text{E} - 07 + 7.40047\text{E} - 08})$$

= 6.58 Km.

School distance calculation 2:
SMAN 2: lat2 -6.3946006 and long2 106.8491576

$$\Delta lat = \frac{\pi}{180} * (lat2 - lat1)$$

$$= \frac{3.14}{180} * (-6.3946006 - (-6.344740)) = -0.00087$$

$$\Delta long = \frac{\pi}{180} * (long2 - long1)$$

$$= \frac{3.14}{180} * (106.8491576 - 106.845745) = 5.95\text{E-}05$$

$$a = \sin(\frac{\Delta lat}{2})^2 = a = \sin(\frac{0.00087}{2})^2 = 1.89134\text{E-}07$$

$$c = \cos(lat1) * \cos(lat2) * \sin\left(\frac{\Delta long}{2}\right)^2$$

$$= \cos(-6.344740) * \cos(-6.3946006) * \sin\left(\frac{5{,}95E - 05}{2}\right)^2$$

= 8.78821E-10

$$d = R * 2 * \text{asin}(\sqrt{a + c})$$

$$= 6371 * 2 * \text{asin}(\sqrt{1.89134\text{E} - 07 + 8.78821E - 10})$$

= 5.55 Km

School distance calculation 3:
SMAN 3: lat2 -6.4075209 and long2 106.8409172

$$\Delta lat = \frac{\pi}{180} * (lat2 - lat1)$$

$$= \frac{3.14}{180} * (-6.4075209 - (-6.344740)) = 0.001095$$

$$\Delta long = \frac{\pi}{180} * (long2 - long1)$$

$$= \frac{3.14}{180} * (106.8409172 - 106.845745) = 8.4\text{E-}05$$

$$a = \sin(\frac{\Delta lat}{2})^2 = a = \sin(0.001095)^2 = 2.99854\text{E-}07$$

$$c = \cos(lat1) * \cos(lat2) * \sin\left(\frac{\Delta long}{2}\right)^2$$

$$= \cos(-6.344740) * \cos(-6.4075209) * \sin\left(\frac{0.0006398.4E - 5}{2}\right)^2$$

= 1.75949E-09

$$d = R * 2 * \text{asin}(\sqrt{a + c})$$

$$= 6371 * 2 * \text{asin}(\sqrt{2.99854\text{E} - 07 + 1.75949\text{E} - 09})$$

= 6.99 Km.

School distance calculation 4:
SMAN 4: lat2 -6.393434 and long2 106.882392

$$\Delta lat = \frac{\pi}{180} * (lat2 - lat1)$$

$$= \frac{3.14}{180} * (-6.393434 - (-6.344740)) = 0.000867$$

$$\Delta long = \frac{\pi}{180} * (long2 - long1)$$

$$= \frac{3.14}{180} * (106.882392 - 106.845745) = 0.000639$$

$$a = \sin(\frac{\Delta lat}{2})^2 = a = \sin(\frac{0.000867}{2})^2 = 1.87872\text{E-}07$$

$$c = \cos(lat1) * \cos(lat2) * \sin\left(\frac{\Delta long}{2}\right)^2$$

$$= \cos(-6.344740) * \cos(-6.393434) * \sin\left(\frac{0.000639}{2}\right)^2$$

= 1.01352E-07

$$d = R * 2 * \text{asin}(\sqrt{a + c})$$

$$= 6371 * 2 * \text{asin}(\sqrt{1.87872\text{E} - 07 + 1.01352E - 07})$$

= 6.85 Km.

School distance calculation 5:
SMAN 5: lat2 -6.401151 and long2 106.7666284

$$\Delta lat = \frac{\pi}{180} * (lat2 - lat1)$$

$$= \frac{3.14}{180} * (-6.4011561 - (-6.344740)) = -0.000984$$

$$\Delta long = \frac{\pi}{180} * (long2 - long1)$$

$$= \frac{3.14}{180} * (106.7666284 - 106.845745) = -0.00138$$

$$a = \sin(\frac{\Delta lat}{2})^2 = a = \sin(\frac{0.000984}{2})^2 = 2.42137\text{E-}07$$

$$c = \cos(lat1) * \cos(lat2) * \sin\left(\frac{\Delta long}{2}\right)^2$$

$$= \cos(-6.344740) * \cos(-6.401151) * \sin\left(\frac{0.001382}{2}\right)^2$$

= 4.71995E-07

$$d = R * 2 * \text{asin}(\sqrt{a + c})$$

$= 6371 * 2 * \text{asin}(\sqrt{2{,}42137\text{E}-07 + 4.71995\text{E}-07})$

= 10.77 Km.

School distance calculation 6:
SMAN 6: lat2 -6.3706803 and long2 106.7733785

$$\Delta lat = \frac{\pi}{180} * (lat2 - lat1)$$

$= \frac{3.14}{180} * (-6.3706803 - (-6.344740)) = -0.000453$

$$\Delta long = \frac{\pi}{180} * (long2 - long1)$$

$= \frac{3.14}{180} * (106.7733785 - 106.845745) = 0.00126$

$a = \sin(\frac{\Delta lat}{2})^2 = a = \sin(\frac{0{,}000453}{2})^2 = 5.11923\text{E-}08$

$$c = \cos(lat1) * \cos(lat2) * \sin\left(\frac{\Delta long}{2}\right)^2$$

$= \cos(-6.344740) * \cos(-6.3706803) * \sin\left(\frac{0{,}00126}{2}\right)^2$

= 3.96134E-07

$$d = R * 2 * \text{asin}(\sqrt{a + c})$$

$= 6371 * 2 * \text{asin}(\sqrt{5.11923\text{E}-08 + 3.96134\text{E}-07})$

= 8.52Km.

School distance calculation 7:
SMAN 7: lat2 -6.3975893 and long2 106.9100008

$$\Delta lat = \frac{\pi}{180} * (lat2 - lat1)$$

$= \frac{3.14}{180} * (-6.3975893 - (-6.344740)) = -0.000922$

$$\Delta long = \frac{\pi}{180} * (long2 - long1)$$

$= \frac{3.14}{180} * (106.9100008 - 106.845745) = 0.001121$

$a = \sin(\frac{\Delta lat}{2})^2 = a = \sin(\frac{0.000922}{2})^2 = 2.12487\text{E-}07$

$$c = \cos(lat1) * \cos(lat2) * \sin\left(\frac{\Delta long}{2}\right)^2$$

$= \cos(-6.344740) * \cos(-6.3975893) * \sin\left(\frac{0{,}001121}{2}\right)^2$

= 3.11464E-07

$$d = R * 2 * \text{asin}(\sqrt{a + c})$$

$= 6371 * 2 * \text{asin}(\sqrt{2.12487\text{E}-07 + 3.14464\text{E}-07})$

= 9.22 Km.

School distance calculation 8:
SMAN 8: lat2 -6.424844 and long2 106.8468016

$$\Delta lat = \frac{\pi}{180} * (lat2 - lat1)$$

$= \frac{3.14}{180} * (-6.424844 - (-6.344740)) = -0.001397$

$$\Delta long = \frac{\pi}{180} * (long2 - long1)$$

$= \frac{3.14}{180} * (106.8468016 - 106.845745) = 1.84\text{E-}05$

$a = \sin(\frac{\Delta lat}{2})^2 = a = \sin(\frac{0.001397}{2})^2 = 4.88161\text{E-}07$

$$c = \cos(lat1) * \cos(lat2) * \sin\left(\frac{\Delta long}{2}\right)^2$$

$= \cos(-6.344740) * \cos(-6.424844) * \sin\left(\frac{1.84\text{E}-05}{2}\right)^2$

= 8.39228E-11

$$d = R * 2 * \text{asin}(\sqrt{a + c})$$

$= 6371 * 2 * \text{asin}(\sqrt{4.88161\text{E}-07 + 8.39228\text{E}-11})$

= 8.90 Km.

School distance calculation 9:
SMAN 9: lat2 -6.3472217 and long2 106.7801344

$$\Delta lat = \frac{\pi}{180} * (lat2 - lat1)$$

$= \frac{3.14}{180} * (-6.3472217 - (-6.344740)) = -4.329\text{E-}05$

$$\Delta long = \frac{\pi}{180} * (long2 - long1)$$

$= \frac{3.14}{180} * (106.7801344 - 106.845745) = -0{,}00114$

$a = \sin(\frac{\Delta lat}{2})^2 = a = \sin(\frac{4.329\text{E}-05}{2})^2 = 4.68547\text{E-}10$

$$c = \cos(lat1) * \cos(lat2) * \sin\left(\frac{\Delta long}{2}\right)^2$$

$= \cos(-6.344740) * \cos(-6.3472217) * \sin\left(\frac{0.00114}{2}\right)^2$

= 3.26203E-07

$$d = R * 2 * \text{asin}(\sqrt{a + c})$$

$= 6371 * 2 * \text{asin}(\sqrt{4.68547\text{E}-10 + 3.26203\text{E}-07})$

= 7.28 Km.

School distance calculation 10:
SMAN 10: lat2 -6.3932982 and long2 106.7327226

$$\Delta lat = \frac{\pi}{180} * (lat2 - lat1)$$

$= \frac{3.14}{180} * (-6.3932982 - (-6.344740)) = -0.000847$

$$\Delta long = \frac{\pi}{180} * (long2 - long1)$$

$= \frac{3.14}{180} * (106.7327226 - 106.845745) = -0.00197$

$a = \sin(\frac{\Delta lat}{2})^2 = a = \sin(\frac{0.000847}{2})^2 = 1.79382E-07$

$$c = \cos(lat1) * \cos(lat2) * \sin\left(\frac{\Delta long}{2}\right)^2$$

$$= \cos(-6.344740) * \cos(-6.3932982) * \sin\left(\frac{0.00114}{2}\right)^2$$

$$= 9.64099E-07$$

$$d = R * 2 * \text{asin}(\sqrt{a + c})$$

$$= 6371 * 2 * \text{asin}(\sqrt{(1.79382E - 07 + 9.64099E - 07)}$$

$$= 13.63 \text{ Km.}$$

School distance calculation 11:
SMAN 11: lat2 -6.4216667 and long2 106.8367389

$$\Delta lat = \frac{\pi}{180} * (lat2 - lat1)$$

$= \frac{3.14}{180} * (-6.4216667 - (-6.344740)) = -0.001347$

$$\Delta long = \frac{\pi}{180} * (long2 - long1)$$

$= \frac{3.14}{180} * (106.8367389 - 106.845745) = -0.00016$

$a = \sin(\frac{\Delta lat}{2})^2 = a = \sin(\frac{0.001347}{2})^2 = 4.53721E-07$

$$c = \cos(lat1) * \cos(lat2) * \sin\left(\frac{\Delta long}{2}\right)^2$$

$$= \cos(-6.344740) * \cos(-6.4216667) * \sin\left(\frac{0.00016}{2}\right)^2$$

$$= 6.09972E-09$$

$$d = R * 2 * \text{asin}(\sqrt{a + c})$$

$$= 6371 * 2 * \text{asin}(\sqrt{(4.53721E - 07 + 6.09972E - 09)}$$

$$= 8.64 \text{ Km.}$$

School distance calculation 12:
SMAN 12: lat2 -6.4200047 and long2 106.794943

$$\Delta lat = \frac{\pi}{180} * (lat2 - lat1)$$

$= \frac{3.14}{180} * (-6.4200047 - (-6.344740)) = -0.001313$

$$\Delta long = \frac{\pi}{180} * (long2 - long1)$$

$= \frac{3.14}{180} * (106.794943 - 106.845745) = -0.00089$

$a = \sin(\frac{\Delta lat}{2})^2 = a = \sin(\frac{0.001313}{2})^2 = 4,3096E-07$

$$c = \cos(lat1) * \cos(lat2) * \sin\left(\frac{\Delta long}{2}\right)^2$$

$$= \cos(-6.344740) * \cos(-6.4200047) * \sin\left(\frac{0.00089}{2}\right)^2$$

$$= 1,9414E-07$$

$$d = R * 2 * \text{asin}(\sqrt{a + c})$$

$$= 6371 * 2 * \text{asin}(\sqrt{(4,3096E - 07 + 1,9414E - 07)}$$

$$= 10.07 \text{ Km.}$$

School distance calculation 13:
SMAN 13: lat2 -6.376502 and long2 106.873379

$$\Delta lat = \frac{\pi}{180} * (lat2 - lat1)$$

$= \frac{3.14}{180} * (-6.376502 - (-6.344740)) = -0,000554$

$$\Delta long = \frac{\pi}{180} * (long2 - long1)$$

$= \frac{3.14}{180} * (106.873379 - 106.845745) = 0,000482$

$a = \sin(\frac{\Delta lat}{2})^2 = a = \sin(\frac{0.000554}{2})^2 = 7,67485E-08$

$$c = \cos(lat1) * \cos(lat2) * \sin\left(\frac{\Delta long}{2}\right)^2$$

$$= \cos(-6.344740) * \cos(-6,376502) * \sin\left(\frac{0.000482}{2}\right)^2$$

$$= 5,77331E-08$$

$$d = R * 2 * \text{asin}(\sqrt{a + c})$$

$$= 6371 * 2 * \text{asin}(\sqrt{7,67485E - 08 - 07 + 5,77331E - 08})$$

$$= 4.67 \text{ Km.}$$

Based on the calculation the calculation with Haversine formula, the distance value is shown in table 2.

Table 2 describes the results of the calculation manually based on the Haversine algorithm, and the nearest distance from student's domicile is SMAN 13.

Data on the location of the same student's domicile tested against the smart zoning system, it produces data as shown in Figure 6.

Table 2. *Table of Haversine Algorithm Calculation Result Manually.*

NO	User Coordinates		School Name	School Coordinates		Distance (KM)
	Latitude	Longitude		Latitude	Longitude	
1			SMA Negeri 1	-6,395047	106,814458	6,58
2			SMA Negeri 2	-6,3946006	106,8491576	5,55
3			SMA Negeri 3	-6,4075209	106,8409172	6,99
4			SMA Negeri 4	-6,394434	106,8823928	6,85
5			SMA Negeri 5	-6,4011561	106,7666284	10,77
6			SMA Negeri 6	-6,3706803	106,7733785	8,52
7	-6,34474	106,845,745	SMA Negeri 7	-6,3975893	106,9100008	9,22
8			SMA Negeri 8	-6,424844	106,8468016	8,90
9			SMA Negeri 9	-6,3472217	106,7801344	7,28
10			SMA Negeri 10	-6,3932982	106,7327226	13,63
11			SMA Negeri 11	-6,3868742	106,8303999	8,64
12			SMA Negeri 12	-6,4200047	106,794943	10,07
13			SMA Negeri 13	-6,376502	106,873379	4,67

NO	NAMA SEKOLAH	ALAMAT	KECAMATAN	JARAK	DETAIL
1	SMA NEGERI 13 DEPOK	Jl. Pedurenan Depok No.14, RT.04/RW.02, Cisalak Ps., Kec. Cimanggis, Kota Depok, Jawa Barat 16452	Cimanggis	4.61 Km	Detail Sekolah
2	SMA NEGERI 2 DEPOK	Jl. Gede No.177, Abadijaya, Kec. Sukmajaya, Kota Depok, Jawa Barat 16417	Sukmajaya	5.45 Km	Detail Sekolah
3	SMA NEGERI 1 DEPOK	Jl. Nusantara Raya No.317, Depok Jaya, Kec. Pancoran Mas, Kota Depok, Jawa Barat 16432	Pancoran Mas	6.45 Km	Detail Sekolah
4	SMA NEGERI 4 DEPOK	Jl. Jeruk Raya No.1, Sukatani, Kec. Tapos, Kota Depok, Jawa Barat 16454	Tapos	6.79 Km	Detail Sekolah
5	SMA NEGERI 3 DEPOK	Jl. Raden Saleh Raya No.45, RT.3/RW.5, Sukmajaya, Kec. Sukmajaya, Kota Depok, Jawa Barat 16412	Sukmajaya	6.88 Km	Detail Sekolah
6	SMA NEGERI 9 DEPOK	Perumahan Megapolitan, Jalan Bali, Cinere, Kec. Cinere, Kota Depok, Jawa Barat 16514	Cinere	7.21 Km	Detail Sekolah
7	SMA NEGERI 6 DEPOK	Jl. Limo Raya No.28, Limo, Kec. Limo, Kota Depok, Jawa Barat 16514	Limo	8.42 Km	Detail Sekolah
8	SMA NEGERI 11 DEPOK	SMAN 11 Depok Jl. Kemang II Sukma Jaya Kec. Sukma Jaya Kota depok Jawa barat	Sukmajaya	8.53 Km	Detail Sekolah
9	SMA NEGERI 8 DEPOK	Jl. M. Nasir No.84, Cilodong, Kec. Cilodong, Kota Depok, Jawa Barat 16414	Cilodong	8.79 Km	Detail Sekolah
10	SMA NEGERI 7 DEPOK	Jl. Masjid Al-Amsir, Leuwinanggung, Kec. Tapos, Kota Depok, Jawa Barat 16456	Tapos	9.18 Km	Detail Sekolah
11	SMA NEGERI 12 DEPOK	Jl. Gg. H.Bahrudin, Cipayung, Kec. Cipayung, Kota Depok, Jawa Barat 16437	Cipayung	9.96 Km	Detail Sekolah
12	SMA NEGERI 5 DEPOK	Perum Bukit Rivaria Sektor IV, Bedahan, Sawangan, Bedahan, Kec. Sawangan, Kota Depok, Jawa Barat 16519	Sawangan	10.66 Km	Detail Sekolah
13	SMA NEGERI 10 DEPOK	Jl. Raya Curug, RT.1/RW.6, Curug, Kec. Bojongsari, Kota Depok, Jawa Barat 16517	Bojongsari	13.52 Km	Detail Sekolah

Figure 6. *Result of Haversine Formula Calculation by System Smart Zoning.*

In Figure 7, the results of the calculation automatically using a smart zoning system for coordinates of the same student's domicile, namely latitude -6.344740 and longitude 106.845745. The address of residence is on Jalan Bhineka IV, Pasir Gunung Selatan, Cimanggis, with the nearest distance of 4.61 km which is SMAN 13. The data in table 3 has been sorted based on the nearest to the farthest results of the distance calculation.

In addition to the distance table, implementation of the smart zoning system for calculating the nearest distance using the Haversine algorithm also displays a visualization map of student's domicile distance from school, as shown in Figure 7.

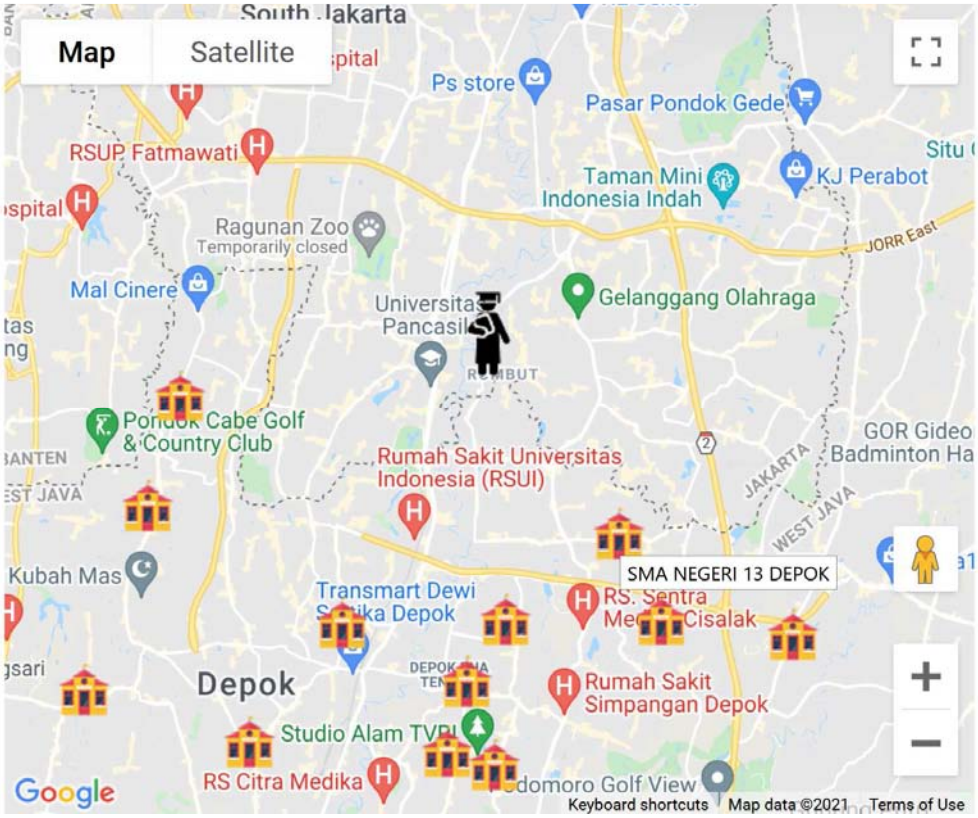

Figure 7. *Visualization of Map Location Distance from Student's Domicile to School.*

The system also provides information that helps and makes it easier for students to get to the location of the school with the visualization of alternative routes that can be taken as shown in Figure 8.

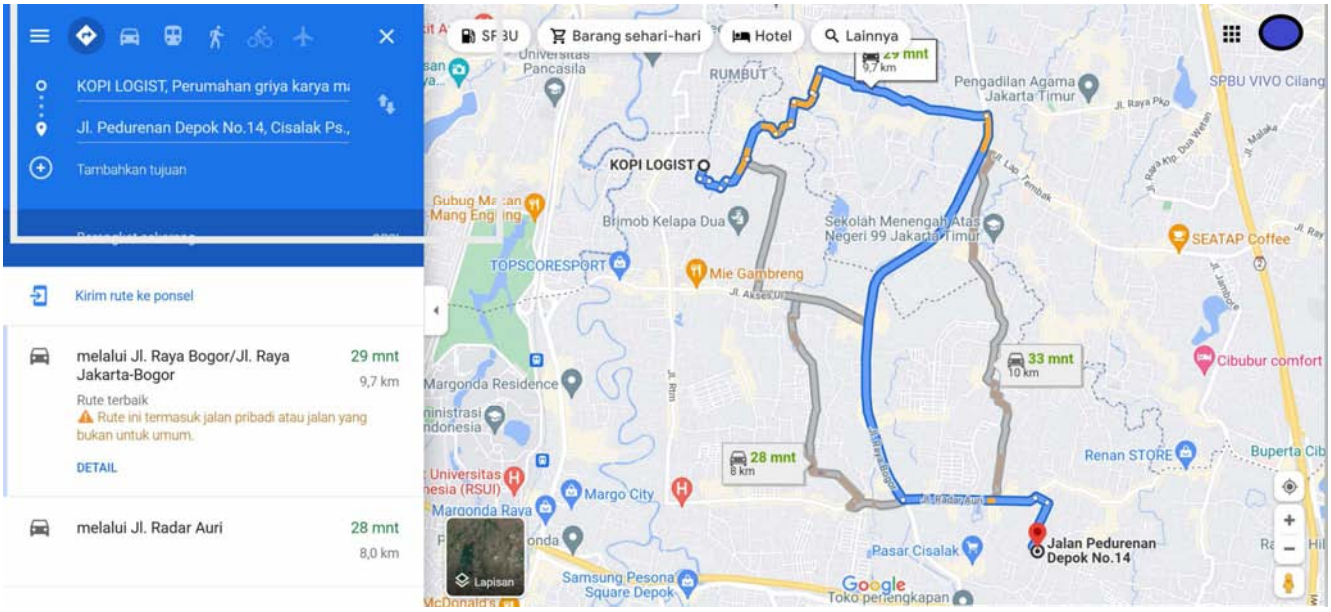

Figure 8. *Visualisation Alternate Route to Destination School.*

4.2. Evaluation and Comparison Result Analysis of Distance Calculation

The distance calculations carried out in this study have been tested using manual calculations based on the Haversine algorithm as shown in table 2. The distance calculation trials have also been carried out automatically using a smart zoning system using the Haversine algorithm shown in table 3. Both tables illustrate the results of the calculations that have similarities where the nearest school distance is SMAN 13

from student's domicile.

In the following, a comparison will be made between the results of calculations manually with the Haversine algorithm with the distance calculated from the Google Maps API (Google Earth) to get the accuracy of the results, as shown in the table 3.

Table 3. *Table of Results Calculating Accuracy of Haversine Manually with Result of Google API [16].*

NO	User Coordinates		Name of School	School Coordinates		Manual of Haversine	Google API	%
	Latitude	Longitude		Latitude	Longitude	Distance (km)	Distance (km)	Error
1			SMA Negeri 1	-6.395047	106.814458	6.58	6.54	0.61
2			SMA Negeri 2	-6.3946006	106.8491576	5.55	5.50	0.91
3			SMA Negeri 3	-6.4075209	106.8409172	6.99	6.97	0.29
4			SMA Negeri 4	-6.394434	106.8882392	6.85	6.85	0
5			SMA Negeri 5	-6.4011561	106.7666284	10.77	11.89	9.42
6			SMA Negeri 6	-6.3706803	106.7733785	8.52	8.50	0.24
7	-6.34474	106.845745	SMA Negeri 7	-6.3975893	106.9100008	9.22	9.19	0.33
8			SMA Negeri 8	-6.424844	106.8468016	8.90	8.83	0.79
9			SMA Negeri 9	-6.3472217	106.7801344	7.28	7.04	3.41
10			SMA Negeri 10	-6.3932982	106.7327226	13.63	13.66	0.22
11			SMA Negeri 11	-6.3868742	106.8303999	8.64	8.61	0.35
12			SMA Negeri 12	-6.4200047	106.794943	10.07	11.31	10.96
13			SMA Negeri 13	-6.376502	106.873379	4.67	4.71	0.85
Rata-Rata Error (%)								2.18
Accuracy (100%-Rata-rata Error)								97.82

The accuracy value of Haversine calculation manually with Google API (Earth) got a value of 97.82%, this explains that the value of calculating distance manually using the Haversine algorithm has good accuracy.

Comparison calculations were also carried out between the results of system calculations using the Haversine formula and the distance calculated from the Google Maps API (Google Earth) to get the accuracy of the results, as shown in table 4.

Table 4. *Table of Results Calculating Accuracy of Haversine by System Smart Zoning with Result of Google API [16].*

NO	User Coordinates		Name of School	School Coordinates		Haversine by smart	Google API	%
	Latitude	Longitude		Latitude	Longitude	zonation System (km)	Distance (km)	Error
1			SMA Negeri 1	-6.395047	106.814458	6.45	6.54	1.38
2			SMA Negeri 2	-6.3946006	106.8491576	5.45	5.50	0.91
3			SMA Negeri 3	-6.4075209	106.8409172	6.88	6.97	1.29
4			SMA Negeri 4	-6.394434	106.8882392	6.79	6.85	0.88
5			SMA Negeri 5	-6.4011561	106.7666284	10.66	11.89	10,34
6			SMA Negeri 6	-6.3706803	106.7733785	8.42	8.50	0.94
7	-6.34474	106.845745	SMA Negeri 7	-6.3975893	106.9100008	9.18	9.19	0.11
8			SMA Negeri 8	-6.424844	106.8468016	8.79	8.83	0.45
9			SMA Negeri 9	-6.3472217	106.7801344	7.21	7.04	2.41
10			SMA Negeri 10	-6.3932982	106.7327226	13.52	13.66	1.02
11			SMA Negeri 11	-6.3868742	106.8303999	8.53	8.61	0.93
12			SMA Negeri 12	-6.4200047	106.794943	9.96	11.31	11.94
13			SMA Negeri 13	-6.376502	106.873379	4.61	4.71	2.12
Rata-Rata Error (%)								2.78
Accuracy (100%-Rata-rata Error)								97.22

The accuracy value of the Haversine calculation using a system with Google API (Earth) got a value of 97.22%, explaining that the distance calculation value using a system with the Haversine formula has good accuracy.

Based on the comparison results from table 3 with table 4, it is explained that the calculation of distance using a straight line with the Haversine formula has good accuracy after being compared with the results of Google API (Earth) calculation. The smart zoning system can be used to calculate the distance between two points, in this case the location of student's domicile with the location of the school and provides a good calculation value because it has a high accuracy value.

5. Conclusion

Based on the results and discussion above, it can be concluded that the Haversine formula can be implemented to solve the problem of calculating distances with a straight line to determine the results of calculating the shortest distance in the smart zoning system. The calculation of the shortest distance is used to determine the recommendation of the chosen school based on zoning. In this study, the implementation of the Haversine formula uses a web-based system to complete the calculation of the nearest path between the coordinates of student's domicile and the

coordinates of the school which is sorted in ascending order within a scope that has been limited to a certain radius, which is zoning in Depok. The accuracy of the calculation results obtained in this study are 97.22% which explains that the system can be used to calculate the nearest distance using the Haversine formula.

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