The Medical Facilities Selection Based on Location-Based Services Application Using SAW and TOPSIS Algorithm

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Abstract. Emergencies are occurring in any situation. The best decision is needed in an emergency situation, such as accidents, heart attacks, and parturition. Google Maps only presents information about the closest distance and time based on Google's algorithm, without considering the best option of medical facilities based on condition in real situation. Furthermore, in this study, the decision support systems, Simple Additive Weighting (SAW), was built then combined with Google Maps API. The Haversine formula was used to get the value of radius, travel distance, and time. The system was compared to other decision support system algorithm, TOPSIS, to understand the suitable method of this system. The scopes of Medical services in this study are hospital, clinic, and PUSKESMAS. Based on experiment that is conducted on 30 data, SAW yields an accuracy of 80, while TOPSIS is 90%. While working on 10 experiments from different user coordinate points, SAW produced 70% accuracy and TOPSIS 80% compared to human experience.

1. Introduction

The information of the medical services is important by people in densely populated cities such as Samarinda [1] [2]. This case is an important factor in determining which the medical services are appropriate with and to be chosen. This study has led to the idea of making a location-based service (LBS) application for selecting the medical facilities in Samarinda based on mobile web. This system builds with GPS (Global Positioning System) integrated with the Google Maps API. This system will show the condition around us about the availability of medical services and detect our current position using GPS [3]. Furthermore, many cases of emergencies, such as accidents, heart attacks, and parturition that are not handled immediately because many people do not know the nearest medical facilities location. Emergencies can occur in any situation. The best decision is needed in an emergency situation, but in complicated condition, many people cannot think logically. Google Maps only presents information about the closest distance and time based on Google's algorithm, without considering the best option of medical facilities based on condition in real situation such as traffic jam and flooded road. Furthermore, in this study, the decision support systems, was built then combined with Google Maps API. Simple Additive Weighting (SAW) algorithm is used in this system. The SAW method is successfully applied in various cases [4]. SAW is a decision support system (DSS) method that is a simple one and many used in modeling of expert experience.

The scopes of Medical services in this study are hospital, clinic, and PUSKESMAS (the health center in sub district). Radius, travel distance, travel time, and traffic density are criteria used in this study. This study is expected to provide information accurately and quickly regarding to the need of a nearby medical facilities using SAW algorithm to know the suitable algorithm for this system. The
Haversine formula was used to get the value of travel distance, radius, and time. The system was compared to other decision support system algorithm, TOPSIS, to understand the suitable method of this system. The procedure of SAW and TOPSIS algorithm is defined in chapter II, then step by step of SAW and TOPSIS calculation described in chapter III, while the results and discussion of this system is presented in chapter IV with tests performed includes: testing the algorithm SAW, TOPSIS algorithm testing, and testing with human perception.

2. Literature Review

This section including related study, Simple Additive Weighting algorithm, TOPSIS algorithm, and Haversine formula, then Google Maps.

2.1. Related Study

In conducting this research, several references related to the object, especially from previous studies were used.

Chu and Huang [5] built the system that makes many People have self-planning of itineraries based-on website, but it has a lack of travel information and regular set itineraries. This study develops a travel planning platform by utilizing Google Maps API and through TraNews, data sources have been constructed by users and users’ positive system experience. This case enhance the users’ travel intention and experiences then accommodate the users arrange itineraries.

Meng, Zhao and Chu [6] developed Google Maps based power failure monitoring and locating system. The system is built to protecting the user’s electricity supply that is priority of electrical service and because the industrial power is the basis of national development. This study proposes an electrical repair system by using Google Maps in monitoring the fault and accident statistics.

Yousif and Elameer [7] built Google maps based expert system for the tourism destinations in Iraq. This system has delivered a navigation information system for tourist and provided great services in exploring their own tourist destinations.

Swastikasari et al [8] designed android based application entitled is E-Kost. This application assists the SWCU students from other cities to find room. Based on this case, the authors have tried to accommodate it by developing an LBS-based application using Object oriented Business Application Development Method and Code Igniter Framework is used in this work.

Rahman et al [9] developed real time Google map and Arduino based vehicle tracking system. The system combines Global Positioning System (GPS) and Global system for mobile communication (GSM) technology. GPS module provides geographic coordinates while GSM module transmits the location of vehicle in terms of latitude and longitude. Other research is conducted by Putra et al [10]. They designed Android-based E-Land mobile application to simplify the Land Office and the communities. The utilization of GPS technology on mobile has a function to get location in performing a survey and determining the coordinate points of a ground area.
Amorim et al [11] developed the system for emergency medical selection using metadata-model based simulation and local search method. Meta model-based simulation used Gaussian process. The system was used Google Maps API for processed data. This study combined of patients' acuity and ensuring all patients has acceptable levels of services. Abdullah et al [12] was developed the best solution for ambulance location selection. Interval Fuzzy Type 2 combined with Simple additive weighting method deployed for this system. Four criteria and five alternatives are calculated using IT2 FSAW to get the best option of ambulance in strategic location. These criteria are response time, demand, coverage area, ambulance workload. Tezcan Sahin et al [13] conducted decision support system using analytical hierarchy Process (AHP). Six criteria and 19 sub criteria were used. The case study is districts in Mugla. This study examined the suitability of methods and approaches for the hospital site selection problems. Meanwhile, the weights obtained for the criteria should be revised in different sites and recalculated. Harja et al [14] built the nearest medical services using Google Maps API, Haversine Formula and TOPSIS algorithms. The researchers focused on the best medical facility based on TOPSIS algorithm. The study compared the Google Maps API TOPSIS with Haversine formula. Based on above studies, this study tries to rank the closest appropriate location based on several of criteria. The criteria that used in this study are radius, travel distance, travel time, traffic density. Then in this study, two methods SAW and TOPSIS are compared to determine the accuracy of the algorithm to be applied in this case.

2.2. Simple Additive Weighting

The Simple Additive Weighting (SAW) method is a method that calculates a weighted sum of performance rating on each alternative in all attributes. This method also requires a process of decision matrix normalizing to a scale that could be compared with all the rating of the alternatives. The normalized matrix is multiplied by the defined weights [15]. As shown in Equation 1 is to calculate the attribute of benefit.

\[
r_{ij} = \frac{x_{ij}}{\max(x_{ij})}
\]  

For calculating the attribute of cost could use Equation 2,

\[
r_{ij} = \frac{-min(x_{ij})}{x_{ij}}
\]

Where:
- \( r_{ij} \) = The normalized performance rating of alternative Ai on attribute Cj
- \( x_{ij} \) = Row and column of a matrix
- \( i \) = alternative, \( j \) = criteria,
- \( \max(x_{ij}) \) = Maximum value of alternative i to criteria j,
- \( \min(x_{ij}) \) = Minimum value of alternative i to criteria j.

Equation 3 is used to calculate the value of the preference for each alternative.

\[
V_i = \sum_{j=1}^{n} w_j \cdot r_{ij}
\]

Where:
- \( V_i \) = Final value of the alternative
- \( w_j \) = The weights
- \( r_{ij} \) = Matrix normalization
The steps of SAW method are:
1. Determining the criteria that used as a reference in decision-making i.e. Ci.
2. Determining the suitability rating of each alternative on each criterion.
3. Making decisions based on criteria matrix (Ci).
4. Normalizing matrix based on the adapted equation with the benefit attribute type (attribute or cost attribute) so it is obtained normalized matrix R.
5. Obtaining the ranking process, namely, the sum of normalized matrix R with the weight vector in order to obtain the greatest value which is selected as the best alternative (Ai) as the solution

2.3. TOPSIS
Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [16] is a method of Multi-Criteria Decision Making (MCDM). It is widely applied in the literature to rank the alternatives based on their crisp ratings against the evaluation criteria. The basic concept of this method is the best chosen alternative not only has the shortest distance from the positive ideal solution that is maximizing the benefits criteria and minimizing the cost criteria, but also has the longest distance from the negative ideal solution that is maximizing cost criteria and minimizing the benefit criteria [17].

This research uses FTOPSIS method which steps as shown below [16].
1. Form a committee of decision makers, and identify the evaluation criteria and alternatives.
2. Form a decision matrix and evaluate the ranking of each criterion according to their importance.
3. Normalize the decision matrix.
4. Construct the weighted normalized fuzzy decision matrix.
5. Calculate the fuzzy positive ideal solution (FPIS, A^+) and fuzzy negative ideal solution (FNIS, A^-).
6. Calculate the distance of each alternative from FPIS and FNIS.
7. Calculate the closeness coefficient of each alternative.
8. Rank the alternatives based on the closeness coefficient of each alternative’s to the ideal solution

2.4. Haversine Formula
The Haversine formula is a linear distance method. Linear distance is a measurement of the distance between two points on the earth’s surface in the form of a straight line parallel [18]. Linear distance is used to measure the distance from the user's position to the location of the medical facilities. Meanwhile, to get to the location of a medical facility, the measurement method used by Google is traveling distance. Traveling distance measures the distance from one place to another based on travel routes. Therefore, the distance becomes larger and cannot be estimated accurately. The Haversine formula method was created when the level of precision of the calculation results was still very limited. But now, computer calculations can provide a very accurate level of precision so that by using a simple spherical law of cosine formula, we can determine the position quite accurately. Equation 1 is Haversine formula, with d is distance and R is radian.

\[ d = \text{acos} (\sin(lat1) \cdot \sin(lat2) + \cos(lat1) \cdot \cos(lat2) \cdot \cos(long2 - long1)) \cdot R \]  

(4)

2.5. Google Maps
Google Maps application programming interface (API) is an application offered by Google that has a JavaScript technology-based. It provides a lot of processing maps service and adding content to maps service. It allows users to embed Google Maps in their own Web pages. The Google map version 3 class is the core class of Google Maps API [19].

Objects of this class define a single map on a web page and this API is fully integrated with the Google AJAX API. This framework allows user to load API key for all supported Google AJAX APIs and also provides a common namespace for each API, allowing different Google APIs to operate together. The user should register the first-time to get Google Maps API secret key through a Google user account.
3. Proposed Method

3.1. The proposed method

There are several criteria that are used for this research including: radius, travel distance, travel time, and traffic density. The data of radius, travel distance, and travel time are obtained from Google Maps combined with Haversine formula, besides level of traffic density is obtained from Department of Transportation in East Kalimantan Province and from observation. The procedure of this study is explained in Figure 1.

**Figure 1. The Proposed Method**

After getting all of criteria, the next step is calculated Simple Additive Weighting and TOPSIS to select the best of medical facilities based on rank. In this study, medical facilities are not only hospital but also clinic, doctor and puskesmas. The example of medical facilities data is in this study from Samarinda. The Haversine formula combine with Google Maps API is used to get the value of radius, travel distance, and time. The Haversine formula is used to calculate the radius (formula 4).

The SQL query is applied with PHP scripts with JSON format which will be used as data exchange between applications and database servers online. Haversine formula in SQL format is as follows:

```
("SELECT name, id, ((((acos(sin(:latitude*pi()/180))*sin(:lat*pi()/180))+cos(:latitude*pi()/180))*cos(:lat*pi()/180)*cos((:longitude-`lng`)*pi()/180))*60*1.1515*1.609344) as distance FROM location WHERE type = 'hospital' HAVING distance <= :radius ORDER BY distance ASC");
```

The SQL script above is generated for searching nearby hospitals. Variables latitude and longitude are user's position point. Variables lat and lng are from table. The result of SQL script is to display a list of hospital names and the total distance from the user's position. Distance is in units of kilometers. The system changes the distance into kilometers. The value of distance using Haversine formula is radius. The value of travel distance and travel time are from Google Maps.

3.2. Step by Step SAW Algorithm
The SAW procedures are explained as follows:

3.2.1. Determining criteria
The criteria attribute in SAW method is divided into two categories, i.e. benefit and cost. The greatest value is the best value called benefit criteria while the smallest one is the best value called cost criteria. For this study, the benefit criteria are radius, distance, time and traffic, while the cost criteria are travel distance and travel time.
criteria is none. The weight of each criteria based on human experience, after that, the questionnaire results is calculated using pairwise comparison matrix [20]. The criteria used in the Medical Facilities selection in Samarinda is shown in Table I.

### TABLE I. DETERMINING CRITERIA

| Criteria | Weight |
|----------|--------|
| C1 Radius | 0.1    |
| C2 Distance | 0.25 |
| C3 Time | 0.4    |
| C4 Density | 0.25 |

#### 3.2.2. Calculating SAW

The process of Medical Facilities selection used 30 data. In Table II are shown 10 data samples. In this study, the testing data was performed by user’s location position with latitude -0.535765 and longitude 117.123536. The data were obtained from Samarinda, while the criteria included are the value of radius (C1), the value of distance (C2), the value of time (C3), and then the value traffic density (C4) follows in Table II.

### TABLE II. SAMPLING DATA OF MEDICAL FACILITIES

| Initial | Employee | C1 | C2 | C3 | C4 |
|---------|----------|----|----|----|----|
| A       | RSUD Inche Abdoel Moeis | 1.8 | 7.87 | 15 | 1  |
| B       | Rumah Sakit Medika Citra | 3.2 | 8.42 | 20 | 3  |
| C       | Rumah Sakit Aisyiyah | 1.7 | 8.93 | 25 | 2  |
| D       | Rumah Sakit Abdul Wahab Syahranie | 2.2 | 9.37 | 30 | 3  |
| E       | Rumah Sakit Dirgahayu | 2.4 | 9.97 | 17 | 2  |
| F       | Puskesmas Sungai Keledang | 1.5 | 2.72 | 10 | 1  |
| G       | Puskesmas Baqa | 2.1 | 4.83 | 19 | 2  |
| H       | Puskesmas Harapan Baru | 2.7 | 5.66 | 12 | 1  |
| I       | BP Klinik Islamic Center | 2.5 | 6.78 | 27 | 1  |
| J       | Puskesmas Karang Asam | 1.9 | 7.97 | 26 | 1  |

Based on Table II, C1 and C2 are in kilometres unit, C3 is in minutes unit, C4 is interval value by Department of Transportation in East Kalimantan Province. The value 1 in density is means uncrowded, value 2 means slowdown, and value 3 means crowded. The next step was to define an alternative that was calculated with the SAW method.

The next step was to determine decision matrix (X). The results of the normalization calculations were obtained normalized matrix (R) in below:

\[
R = \begin{bmatrix}
0.5625 & 0.7894 & 0.5000 & 0.3333 \\
1.0000 & 0.8445 & 0.6667 & 1.0000 \\
0.5313 & 0.8957 & 0.8333 & 0.6667 \\
0.6875 & 0.9398 & 1.0000 & 1.0000 \\
0.7500 & 1.0000 & 0.5667 & 0.6667 \\
0.4688 & 0.2728 & 0.3333 & 0.3333 \\
0.6563 & 0.7332 & 0.6333 & 0.6667 \\
0.8438 & 0.5677 & 0.4000 & 0.3333 \\
0.7813 & 0.8736 & 0.7333 & 0.6667 \\
0.5938 & 0.6800 & 0.9000 & 0.3333 \\
\end{bmatrix}
\]
The process of normalization matrix X (R) is done by calculating each criterion value based on the benefit or cost. Normalization matrix R used equation 1 for benefit whereas equation 2 for cost criteria. For this study, normalization matrix R used equation 1 (Part II, SAW). The final value for ranking was resulted by summing the multiplication of the normalized matrix R with the weight vector so the greatest value was chosen as the best alternative. Thus, the following step was the multiplication of matrix R with weights.

The final step in the selection of Medical facilities using SAW was to specify ranking of the preference from each alternative. This value was calculated by using Equation (3) i.e. by summing the results of the multiplication between the weighting vector (W) and the normalized matrix (R). The Specified weighting vector is W = [0.1 0.25 0.4 0.25] as shown in the example below,

\[ v_1 = (0.05625)(0.1) + (0.19734)(0.25) + (0.2)(0.4) + (0.08333)(0.25) = 0.5369 \]

Based on the calculation, the preference value or ranking in matrix R was multiplied by the weight of each criterion. The last result of SAW is shown in Table V.

### 3.3. Step by Step TOPSIS Algorithm

The benefit and cost criteria should be defined by decision makers. Meanwhile, it is different in TOPSIS algorithm, the decision makers do not require to deep understand which is the benefits and cost criteria. SAW and TOPSIS have same calculation up to step 4 (Part II) that is calculated matrix normalization. The further step is calculating the Positive Ideal Solution (PIS⁺) and the Negative Ideal Solution (NIS⁻) as shown in Table III.

#### Table III. The Value of PIS and NIS of TOPSIS

|       | PIS⁺  | NIS⁻  |
|-------|-------|-------|
| Y1+   | 0.0449| Y1-   | 0.0215|
| Y2+   | 0.1005| Y2-   | 0.0274|
| Y3+   | 0.1839| Y3-   | 0.0613|
| Y4+   | 0.1216| Y4-   | 0.0405|

#### Table IV. The Rank of Every Alternative Using TOPSIS

| Alternative | \(D^+_i\) | \(D^-_i\) | \(CC_i\) |
|-------------|-----------|-----------|----------|
| A           | 0.1259    | 0.2063    | 0.6208   |
| B           | 0.0632    | 0.3572    | 0.8495   |
| C           | 0.0560    | 0.3030    | 0.8440   |
| D           | 0.0152    | 0.3736    | 0.9607   |
| E           | 0.0901    | 0.2946    | 0.7657   |
| F           | 0.1659    | 0.1972    | 0.5431   |
| G           | 0.0845    | 0.2910    | 0.7748   |
| H           | 0.1438    | 0.2005    | 0.5823   |
| I           | 0.0656    | 0.2978    | 0.8194   |
| J           | 0.0910    | 0.2268    | 0.7136   |
After obtaining the value of PIS and NIS, the next step was calculated the distance of each alternative to PIS \((D_i^+)\) and NIS \((D_i^-)\). The distance value was used to calculate the Closeness Coefficient \((CC_i)\) of every alternative. The result is explained in Table IV.

4. Results and Discussion

The 30 data of medical facilities were tested to get the appropriate ones that is the best medical facility. Based on the results of 30 data testing, the accuracy obtained using the SAW method was 80%, while 20% was inaccurate compared to the results of Google Map. It means there are 6 medical facilities data that aren't acceptable. TOPSIS method obtained a higher accuracy of 90%. There are 3 data that aren't appropriate. The alternative chosen was an alternative with the higher rank. It means the higher rank has the lowest value. The alternative with lowest value means that was the nearest location from user’s position. The ranking results are shown in Table V. There are differences in rankings for alternatives E, G and J in the data samples. The differences in calculations lead to these results so the accuracy of SAW and TOPSIS also differ.

| Alternative | SAW   | TOPSIS |
|-------------|-------|--------|
| A           | 0.5369 (8) | 0.6208 (8) |
| B           | 0.8278 (2)  | 0.8495 (2)  |
| C           | 0.7770 (3)  | 0.8440 (3)  |
| D           | 0.9537 (1)  | 0.9607 (1)  |
| E           | 0.7183 (5)  | 0.7657 (6)  |
| F           | 0.3317 (10) | 0.5431 (10) |
| G           | 0.6689 (7)  | 0.7748 (5)  |
| H           | 0.4696 (9)  | 0.5823 (9)  |
| I           | 0.7565 (4)  | 0.8194 (4)  |
| J           | 0.6727 (6)  | 0.7136 (7)  |

Based on Table V, the greatest rank is the best option of medical facility. The best medical facility is derived from the lowest calculated value. The lowest value of alternative is indicated that the alternative is more easily accessible.

Furthermore, this study also compared the result with human perception. In this study, the researcher tried to test the two methods with 10 experiments to know the result compared with human perception. The ten experiments are different user’s position and different data. In table VI, is derived the number of testing, the best ranking of SAW, the best ranking of TOPSIS, and the best option of human. The number of alternative for each test performed is 10 medical facilities data from different location of user and varied medical facilities data.

| Testing | SAW | Human | TOPSIS | Human |
|---------|-----|-------|--------|-------|
| 1       | F   | F     | F      | F     |
| 2       | A   | A     | A      | A     |
| 3       | B   | A     | A      | A     |
| 4       | D   | D     | D      | D     |
| 5       | E   | E     | E      | E     |
| 6       | H   | D     | H      | D     |
| 7       | E   | E     | E      | E     |
| 8       | A   | A     | A      | A     |
| 9       | E   | E     | E      | E     |
| 10      | F   | H     | F      | H     |
Based on Table VI, there are ten testing performed to compare the SAW algorithm with human and TOPSIS algorithm to human. In Table VI, three experiments are not appropriate with human experience for SAW. It means that accuracy is only 70% for SAW. Besides TOPSIS has two experiments that are not similar with human then the accuracy is 80%.

5. Conclusions
The SAW and TOPSIS algorithm are able to be combined with Google Maps application for the best medical facilities selection. In the case of searching for locations and trips, there are several factors that can affect the accuracy of getting to the destination. The distance shown by Google Maps is far and sometimes inappropriate. The resulting radius often does not match the actual distance. This is because the path taken is not measured by two points. The actual distance can be further due to the different direction. Therefore, the value of distance and the traffic density become important points in decision making. The shortest distance does not always indicate a faster travel time. It is caused by traffic jams or damaged road condition or even flooding. Based on experiment that is conducted on 30 data, SAW yields an accuracy of 80, while TOPSIS is 90%. While working on 10 experiments from different user coordinate points, SAW produced 70% accuracy and TOPSIS 80% compared to human experience. These differences in value can be caused by various factors such as road conditions and weather conditions. For further study, the system is able to conduct with other decision algorithm to get more accuracy and the other criteria can added to explore many data.

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