The Ambulance Route Efficiency for Transporting Patients to Referral Hospitals Based on Distance and Traffic Density Using the Floyd-Warshall Algorithm and Google Traffic Assistance

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Abstract. The route of delivering patients using an ambulance is important thing because it relates to a person's life. It Requires finding an efficient route for patient delivery so that it can facilitate the ambulance journey. In this study, the ambulance route from the public-health centers to the referral hospitals will be modeled in a weighted graph where the weight is determined based on distance and traffic density using the Simple Additive Weighting (SAW) method. Traffic density data is taken from google maps at 3 different time conditions in the morning, afternoon, and evening. Then the optimal route is determined on the weighted graph using the Floyd Warshall Algorithm which is an algorithm that can be used to find the shortest path in the weighted graph. In this study, case studies were taken on the optimal route for ambulances from several health centers in the city of Semarang, namely the health centers of Pegandan, Kagok, Sekaran, and Ngesrep to several Referral Hospitals including St. Elisabeth, William Booth, and the Bhakti Wira Tamtama Hospital.

Keywords: Route · ambulance · distance · traffic-density · Floyd-Warshall · Google maps-traffic

1 Introduction

Emergency events can occur anytime and anywhere, and delays in handling emergency events can pose various risks to causing death. Emergency events are caused by anarchist actions, accidents, fires, and then on. In conditions like this, proper and fast emergency management is needed. The Integrated Emergency Management System (SPGDT) is one of the efforts made by the Indonesian government to provide emergency services [1]. In 2021, it was recorded that the total outpatient referral visits in Indonesia were 4,648,738 and outpatients were 239,696 [2]. This proves that improving the quality of services in emergencies and accelerating the response time of victims/patients can reduce mortality due to delays in handling, which is the primary purpose of the SPGDT [3]. The main

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problem often experienced in delivering patients is finding the optimal path or route possible in delivering patients. The problem of delivering patients will use one of the medical facilities, namely ambulances. The optimal route referred to in this study is the route with the shortest path and a low level of density, which is expected to provide the fastest route solution that ambulances can pass in delivering patients.

A graph presents discrete objects and relationships in these objects. The optimal route on a network can be completed using several algorithms in graph theory, including the Djikstra algorithm, Greedy algorithm, Bellman-Ford algorithm, and Floyd-Warshall algorithm [4]. The Floyd-Warshall algorithm is an algorithm used to find the shortest paths between all pairs of vertices in a weighted graph. It calculates the shortest distance matrix and shortest path matrix for every pair of vertices in the graph, considering both direct edges and indirect paths through intermediate vertices [5]. The Floyd-Warshall algorithm is an option for solving this problem because the algorithm can be implemented easily and it is part of a dynamic program that can search all the shortest routes of each possible pair of different places (All-pairs Shortest Path Problem) and is effective in completing the search for the best (optimal) route [6]. Based on the problem of finding the shortest trajectory in the graph, which is part of the optimization problem where the more points and lines on the graph, the more complicated to solve it [7].

Shortening the completion time requires a program to support the search for paths. One of the applications of the Floyd-Warshall algorithm is searching for the shortest trajectory of pharmacy with the implementation of the java programming language [8]. Another implementation of programming languages in searching the shortest trajectory is determining the road network in Semarang City using the Floyd-Warshall algorithm by designing and creating programs with the Visual Basic programming language [9]. Previous research has been carried out on the search for the optimal route of Trans Bantul, Yogyakarta Special Region that connects public facilities in Bantul, Yogyakarta with indicators of time and cost distance [10]. The difference between the research carried out and the previous research is the indicator used to find the optimal trajectory. In addition to distance, the added indicator is the density of the road. These two indicators will be weighted using the SAW (Simple Additive Weighting) method, which is part of the MADM (Multiple Attribute Decision Making) approaches. This method can be used to unite the weights of each indicator so that the weights containing the two indicators are obtained [11, 12, 13]

After obtaining the trajectory weight using this method, iteration will be carried out using the Floyd-Warshall algorithm. This algorithm can find all the shortest trajectories in each possible pair of different places and effectively solve optimization problems. The weight obtained from the results of the iteration can form the shortest route by looking for the trajectory (edge) with the most negligible weight in each pair of points (vertex) [14]. This research utilizes Google Traffic to determine routes and assess road density indicators. Google Traffic is a real-time traffic information service provided by Google. It provides up-to-date data on traffic conditions, congestion levels, and estimated travel times for various roads and routes. The service gathers data from multiple sources, including GPS data from smartphones, anonymous data from Google Maps users, and historical traffic patterns. By analyzing this data, Google Traffic offers users accurate information on current traffic conditions and suggests alternative routes to navigate

around congested areas. While specific sources are not available at the moment, you can refer to Google's official documentation or conduct a search for more details on Google Traffic and its functionality [15].

Based on this description, we are interested in investigating the search for the best route for patient delivery by ambulance using the Floyd-warshall algorithm from the Pegandan Health Center, Sekaran Health Center, Ngesrep Health Center and Kagok Health Center to referral hospitals including St. Elisabeth Hospital, William Booth Hospital and Bhakti Wira Tamtama Hospital in the Semarang City.

2 Material and Methods

The method used in this paper are as follows:

2.1 Data

We use the data on distance and density between any pair of locations which are gathered through Google Maps and Google Maps Traffic. Meanwhile, the data on the ambulances and the referral hospitals are obtained from interviews with the public health centers.

2.2 Data Processing

The initial vertices are health center and the end vertices are hospital Menawhile, the internal vertices represent bends/deviations.

The data on distance is given the score as follows: this data will be converted into weights in each indicator with a range of 1–4. Scoring the distance indicator will use the min-max normalization formula as follows:

$$\frac{e_i - e_{min}}{e_{max} - e_{min}} = \frac{x - 1}{4 - 1}$$

Information:
e_i= Distance i
e_{min} = normalized maximum value
e_{max} = normalized minimum value
i = 1,2,3,…n
x = Skor range [1, 4]

Scoring for road density refers to the color indicator in Google Traffic, dark red, which means very high road density will be given a score of 4, red will be given a score of 3, orange will be given a score of 2, and green which can be interpreted as low road density tends to be smooth will be given a score of 1.

The greater the score that will be given, the higher the density of the road is. The road density in this study will be divided into 3 conditions according to busy times: in the morning around 07.00–10.00, noon at 10.00–13.00, and in the afternoon at 13.00–16.00, on Monday-Saturday. This is based on the operational time of the health center.

Combining the distances and road densities into the weights of edges. The calculation is done using the SAW (Simple Additive Weighting) method and the Python programming language in Google Collaboration software, with the following completion steps:

1) Determining the criteria to be a reference in decision making (C_i) *where*C_1 is a distance indicator and C_2 is an indicator of road density.
2) Determine the match rating of each indicator. This study will use match ratings on each criterion is $C_1 = 0,5$ dan $C_2 = 0,5$ this means that each indicator has the same priority in determining the optimal route.
3) Making a decision matrix using indicators in each predetermined criterion, then normalizing it according to the type of attribute of the problem, in this study it is included in the category of cost attributes (cost) then in its solution will use the equation:

$$dr_{ij} = \frac{\min xij}{xij} \tag{2}$$

4) The final the final step is to determine the alternative value (V_i) through the process of ranking obtained from the summation and multiplication of the normalized matrix by the weight vector (Weight rating match). So that the greatest value will be obtained as the best alternative (A_i) by using the following formula

$$V_i = \sum_{j=1}^{n} w_j r_{ij} \tag{3}$$

Information:
V_i = Alternative end value
w_j= Specified weights
r_{ij}= Normalization of the matrix

2.3 Representing the Vertices and the Edges Between Vertices as the Weighted Graph Models

The Optimal Routes Are Determined Using the Floyd-Warshall Algorithm Where the Calculation is Done Using the Python Programming Language and Google Collaboration Software. Here Are the Steps that Can Be Done

First Step. The first step is to represent the existing graph into a matrix that has a score and the score for each edge is as follows

$$W_{ij} = \begin{cases} 0, \ if \ i = j \\ W_{ij} \ if \ i \neq j \ and \ W_{ij} \in E \\ \infty, \ if \ i \neq j \ and \ W_{ij} \notin E \end{cases} \tag{4}$$

Second Step. Next do an iteration of which for each $W_{[i,j]} > W_{[i,k]} + W_{[k,j]}$ so

1) Can exchange $W_{[i,j]}$ with $W_{[i,k]} + W_{[k,j]}$
2) Exchange $Z_{[i,j]}$ with $Z_{[i,k]}$

The iteration process will be carried out using the Python programming language using Google Collaboratory software to determine the optimal route using the Floyd-Warshall algorithm. The iteration process has been carried out at each health center. Then a matrix will be obtained W* which is the result of the calculation process of the Floyd-Warshall algorithm, which shows the route with the optimal weight between each point of the optimal route of the Z* matrix.

3 Results and Discussion

The research used an ambulance route to deliver patients from each health center to a predetermined referral hospital. The data will be visualized into the initial map of the graph network, where points in the network will represent health centers, hospitals, and turns /crossroads. The number of patient delivery route networks from the Pegandan Health Center to the referral hospital was 27 vertices with 29 edges, as well as the Sekaran Health Center had 37 vertices with 30 edges were obtained, Ngesrep Health Center had 24 vertices with 24 edges, and Kagok Health Center had 25 vertices with 27 edges.

The following are the results of the optimal travel route of the ambulance from each health center to the referral hospital.

3.1 Pegandan Health Center

The following is a table of the optimal route results obtained from the Peganda Health Center (v1.1) as a point of departure to each hospital (Table 1).

3.2 Sekaran Health Center

The following is a table of optimal route results obtained from the Sekaran health center (v1.2) as a point of departure to each hospital (Table 2).

Table 1. Optimal Route of Pegandan Health Center

No	End Point	Optimal Route			Weight		
		Morning	**Noon**	**Afternoon**	**Morning**	**Noon**	**Afternoon**
1.	St. Elisabeth Hospital (z1)	v1.1 – Lamongan Raya – Papandayan – Papandayan No.71 – Sultan Agung – Taman Diponegoro – Kawi Raya – z1	v1.1 – Lamongan Raya – Papandayan – Papandayan No.71 – Sultan Agung – Taman Diponegoro – Kawi Raya – z1	v1.1 – Lamongan Raya – Papandayan – Papandayan No.71 – Sultan Agung – Taman Diponegoro – Kawi Raya – z1	4,455	3,872	3,812
2.	William Booth Hospital (z2)	v1.1 – Lamongan Raya – Papandayan – Papandayan No. 71 – Sultan Agung –Letnan Jenderal S. Parman – z2	v1.1 – Lamongan Raya – Papandayan – Papandayan No. 71 – Sultan Agung –Letnan Jenderal S. Parman – z2	v1.1 – Lamongan Raya – Papandayan – Papandayan No. 71 – Sultan Agung –Letnan Jenderal S. Parman – z2	2,859	2,776	2,776
3.	Bhakti Wira Tamtama Hospial (z3)	v1.1 – Lamongan Raya – Kelud Raya – Kaligarang – Dr. Sutomo – z3	v1.1 – Lamongan Raya – Kelud Raya – Kaligarang – Dr. Sutomo – z3	v1.1 – Lamongan Raya – Kelud Raya – Kaligarang – Dr. Sutomo – z3	2,859	2,776	2,776

Table 2. Optimal Route of Sekaran Health Center

No	End Point	Optimal Route			Weight		
		Morning	**Noon**	**Afternoon**	**Morning**	**Noon**	**Afternoon**
1.	St. Elisabeth Hospital (z1)	v1.2 – Taman Siswa – Raya Banaran – Sekaran Raya –Kolonel HR. Hadijanto – Dewi Sartika – Menoreh Raya – Papandayan – Papandayan 71 – Sultan Agung – Taman Diponegoro – Kawi Raya – z1	v1.2 – Taman Siswa – Raya Banaran – Sekaran Raya –Kolonel HR. Hadijanto – Dewi Sartika – Menoreh Raya – Papandayan – Papandayan 71 – Sultan Agung – Taman Diponegoro – Kawi Raya – z1	v1.2 – Taman Siswa – Raya Banaran – Sekaran Raya –Kolonel HR. Hadijanto – Dewi Sartika – Menoreh Raya – Papandayan – Papandayan 71 – Sultan Agung – Taman Diponegoro – Kawi Raya – z1	7,272	6,522	6,439
2.	William Booth Hospital (z2)	v1.2 – Rambutan – Taman Siswa – Raya Banaran – Sekaran Raya – Kolonel HR. Hadijanto – Dewi Sartika – Menoreh Raya – Papandayan – Papandayan 71 – Sultan Agung –Letnan Jenderal S. Parman – z2	v1.2 – Rambutan – Taman Siswa – Raya Banaran – Sekaran Raya – Kolonel HR. Hadijanto – Dewi Sartika – Menoreh Raya – Papandayan – Papandayan 71 – Sultan Agung –Letnan Jenderal S. Parman – z2	v1.2 – Rambutan – Taman Siswa – Raya Banaran – Sekaran Raya – Kolonel HR. Hadijanto – Dewi Sartika – Menoreh Raya – Papandayan – Papandayan 71 – Sultan Agung –Letnan Jenderal S. Parman – z2	5,886	5,636	5,553
3.	Bhakti Wira Tamtama Hospial (z3)	v1.2 – Rambutan – Taman Siswa – Raya Banaran – Sekaran Raya – Kolonel HR. Hadijanto – Dewi Sartika – Menoreh Raya – Kelud Raya – Kaligarang – Dr. Sutomo – z3	v1.2 – Rambutan – Taman Siswa – Raya Banaran – Sekaran Raya – Kolonel HR. Hadijanto – Dewi Sartika – Menoreh Raya – Kelud Raya – Kaligarang – Dr. Sutomo – z3	v1.2 – Rambutan – Taman Siswa – Raya Banaran – Sekaran Raya – Kolonel HR. Hadijanto – Dewi Sartika – Menoreh Raya – Kelud Raya – Kaligarang – Dr. Sutomo – z3	5,491	5,324	5,158

3.3 Ngesrep Health Center

The following is a table of optimal route results obtained from the Ngesrep Health Center (v1.3) as a point of departure to each hospital (Table 3)

3.4 Kagok Health Center

The following is a table of optimal route results obtained from the Kagok Health Center (v1.4) as a point of departure to each hospital (Table 4).

It is known that the route for delivering patients from each health center to the referral hospital is the same in the morning, afternoon, and evening conditions. The greater the weight gained, the higher the level of road density. The results showed that the Pegandan

Table 3. Optimal Route of Ngesrep Health Center

No	End Point	Optimal Route			Weight		
		Morning	Noon	Afternoon	Morning	Noon	Afternoon
1.	St. Elisabeth Hospital (z1)	v1.3 – Jatingaleh – Carikan III – Carikan – Teuku Umar – Semarang Surakarta – Sultan Agung – Taman Diponegoro – Kawi Raya – z1	v1.3 – Jatingaleh – Carikan III – Carikan – Teuku Umar – Semarang Surakarta – Sultan Agung – Taman Diponegoro – Kawi Raya – z1	v1.3 – Jatingaleh – Carikan III – Carikan – Teuku Umar – Semarang Surakarta – Sultan Agung – Taman Diponegoro – Kawi Raya – z1	8,557	8,308	8,141
2.	William Booth Hospital (z2)	v1.3 – Jatingaleh – Carikan III – Carikan – Teuku Umar – Semarang Surakarta – Sultan Agung – Letnan Jenderal S. Parman – z2	v1.3 – Jatingaleh – Carikan III – Carikan – Teuku Umar – Semarang Surakarta – Sultan Agung – Letnan Jenderal S. Parman – z2	v1.3 – Jatingaleh – Carikan III – Carikan – Teuku Umar – Semarang Surakarta – Sultan Agung – Letnan Jenderal S. Parman – z22	6,408	6,659	6,492
3.	Bhakti Wira Tamtama Hospial (z3)	v1.3 – Jatingaleh – Carikan III – Carikan – Teuku Umar – Semarang Surakarta – Sultan Agung – Letnan Jenderal S. Parman – Dr. Sutomo – z3	v1.3 – Jatingaleh – Carikan III – Carikan – Teuku Umar – Semarang Surakarta – Sultan Agung – Letnan Jenderal S. Parman – Dr. Sutomo – z3	v1.3 – Jatingaleh – Carikan III – Carikan – Teuku Umar – Semarang Surakarta – Sultan Agung – Letnan Jenderal S. Parman – Dr. Sutomo – z3	8,082	8,333	8,040

Table 4. Optimal Route of Kagok Health Center

No	End Point	Optimal Route			Weight		
		Morning	Noon	Afternoon	Morning	Noon	Afternoon
1.	St. Elisabeth Hospital (z1)	v1.4 – Telomoyo – Kagok Dalam 1 – Kawi Raya – z1	v1.4 – Telomoyo – Kagok Dalam 1 – Kawi Raya – z1	v1.4 – Telomoyo – Kagok Dalam 1 – Kawi Raya – z1	1,932	1,848	1,932
2.	William Booth Hospital (z2)	v1.4 – Diponegoro – Sultan Agung – Papandayan – Malabar – Sultan Agung – Letnan Jenderal S. Parman – z2	v1.4 – Diponegoro – Sultan Agung – Papandayan – Malabar – Sultan Agung – Letnan Jenderal S. Parman – z2	v1.4 – Diponegoro – Sultan Agung – Papandayan – Malabar – Sultan Agung – Letnan Jenderal S. Parman – z2	6,027	6,027	5,943
3.	Bhakti Wira Tamtama Hospial (z3)	v1.4 – Telomoyo – Kagok Dalam No.1 – Kawi Raya – Genuk Sari Atas – Diponegoro – Veteran – Letnan Jenderal S. Parman – Dr. Sutomo – z3	v1.4 – Telomoyo – Kagok Dalam No.1 – Kawi Raya – Genuk Sari Atas – Diponegoro – Veteran – Letnan Jenderal S. Parman – Dr. Sutomo – z3	v1.4 – Telomoyo – Kagok Dalam No.1 – Kawi Raya – Genuk Sari Atas – Diponegoro – Veteran – Letnan Jenderal S. Parman – Dr. Sutomo – z3	6,368	6,617	6,035

Health Center route to St. Elisabeth Hospital had the highest road density in the morning at 4,455 and the lowest in the afternoon at 3,812. William Booth Hospital also had the highest density level in the morning with a weight of 2,859 and had the same weight in the afternoon and evening of 2,776. Meanwhile, in the Bhakti Wira Tamtama Hospital, the highest density occurred in the morning at 2,589, and the same road density in the afternoon and evening was 2,776.

Furthermore, the Sekaran Health Center Route to St. Elisabeth Hospital has the highest road density in the morning at 7,272 and the lowest in the afternoon at 6,439. Just like St. Elisabeth Hospital, William Booth Hospital also had the highest density in the morning with a weight of 5,886 and the lowest density in the afternoon of 5,553. Meanwhile, in the Bhakti Wira Tamtama Hospital, the highest density occurred in the

morning at 5,491, and the lowest road density in the afternoon was 5,158. The route from Health Center Ngesrep to St. Elisabeth Hospital results have the highest road density in the morning at 8,557 and the lowest density in the afternoon at 8,141. William Booth Hospital has the highest daily density with a weight of 6,659, and the lowest in the morning is 6,408. Meanwhile, in the Bhakti Wira Tamtama Hospital, the highest density occurred during the day at 8,333. The lowest road density in the afternoon was 8,040. The Kagok Health Center Route to St. Elisabeth Hospital had the highest road density in the morning and evening at 1,932. The lowest density level occurred during the day at 1,848. William Booth Hospital has the highest density in the morning and afternoon, weighing 6,027, and the lowest in the afternoon at 5,943. Meanwhile, in the Bhakti Wira Tamtama Hospital, the highest density occurred during the day at 6,617, and the lowest road density in the afternoon was 6,035.

4 Conclusions and Suggestions

4.1 Conclusions

1. A patient delivery network model was obtained using an ambulance to deliver patients from the health center to the referral hospital using the Floyd-Warshall algorithm and the SAW method and the route that has been determined through Google Traffic with the following steps:
   a. Combining indicators using the SAW (Simple Additive Weighting) method with the first step is to determine the criteria that will be the reference, the second step is to determine the match rating of each indicator and make a decision matrix based on the indicator and carry out a normalization matrix, after which calculate the alternative values obtained by the summation process of the multiplication of the normalized matrix with the weight vector.
   b. Perform calculations using the Floyd-Warshall algorithm using alternative values that have been obtained previously, by presenting the graph into a correlated matrix, iterating, and obtaining the smallest weight between all points where it is the optimal route.
2. Based on the results of system calculations that have been carried out using the Floyd-warshall algorithm with the SAW method, there are several differences as follows:
   a. The Pegandan Health Center goes to William Booth Hospital, with an initial route of 5 km, and a calculated route of 4.8 km. There is a difference of 200 m, the calculation route is more efficient than the distance determined by the health center. In addition, the calculation route tends to be green from the initial route to the health center. So the calculation results obtained will be smoother and will go faster to the destination referral hospital
   b. Sekaran health center to Hospital St. Elisabeth uses a calculation of 9.8 km, and an initial distance of 12 km, a difference of 2.2 km from the calculation route is more efficient than the distance determined by the health center. So the calculation results obtained are smoother and will go faster to the destination referral hospital

c. Sekaran Health Center to William Booth Hospital with an initial route of 10 km and a route using a calculation of 9 km, a difference of 1 km is obtained, the calculation route is more efficient than the distance determined by the health center. So the calculation results obtained are smoother and will go faster to the destination referral hospital
d. Kagok Health Center to William Booth Hospital with an initial route of 3.6 km and a route using a calculation of 2.7 km, a difference of 900 m is obtained, the calculation route is more efficient than the distance determined by the health center. So the calculation results obtained are smoother and will go faster to the destination referral hospital.

5 Suggestion

The future research that can be done, including accountruction an information system an information system of ambulans route based on distance and traffic density.

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