Optimization of Blood Bag Distribution Routes Using AMPL Software and Nearest Neighbor Algorithm (Case Study Of The Indonesian Red Cross Jakarta)

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ABSTRACT

The process of distributing blood bags by the Indonesian Red Cross (PMI) DKI Jakarta uses route selection preferences by ambulance drivers. Basically, this routing problem can impact other aspects such as additional costs, distribution time, fuel use, carbon emissions, and others, so this research needs to propose the best route to minimize travel distance. There are several Hospital Blood Banks (BDRS) in Jakarta that do not receive blood bags at the right time. As an organization authorized to provide blood bag supply, the PMI must distribute blood bag using the 7R concept (Right Time, Right Place, Right Quantity, Right Quality, Right Cost, Right Condition, and Right People). The PMI also has to consider that blood bags are classified as perishable items that need to require fast and precise handling. Therefore, it is necessary to optimize the blood distribution by minimizing travel distance. The optimization model used is the Vehicle Routing Problem (VRP) with AMPL software comparing with the Nearest Neighbor (NN) algorithm. After 4 hours of running the trial, this research has revealed that AMPL software gives the best combination of travel distance than the Nearest Neighbor algorithm, with the differences being approximately 11.52 km.

1. Introduction

The Indonesian Red Cross (PMI) is a government agency authorized to provide blood supplies for its agency and certain hospitals in need. Blood needs cannot be predicted with certainty, so PMI needs to provide adequate bloodstock to overcome the problem. On the other hand, for the bloodstock to be fulfilled, it is necessary to design a blood distribution network from the PMI head office to several hospitals spread across DKI Jakarta. The percentage of fulfilling blood needs in DKI Jakarta can be seen in the **Table 1**.

Table 1 The Fulfillment Percentage of Blood Needs DKI Jakarta 2016

Province	Number of Citizen (People)	Minimal Blood Needed (Blood Bags)	Blood Production (Blood Bags)	The Fulfillment Percentage of Blood Needs (%)
DKI Jakarta	10,277,628	205,553	622,136	302.7

Source: Annual Report of UTD PMI 2016, InfoDatin 2018, Directorate of Primary Health Services [1]

Even though the percentage of fulfilling the blood needs of DKI Jakarta is substantial, this will still have an impact on the management of blood availability. Because blood is classified as perishable goods, the distribution process requires consideration of time, speed, and special handling following blood delivery procedures. Apart from that, aspects of accuracy, flexibility, capacity, and cost also need to be considered so that the blood distribution process becomes more effective and efficient [2,3,4]. In this case, the PMI Head Office, Central Jakarta acts as a depot that provides and serves blood distribution for 40 Hospital Blood Banks (BDRS) in DKI Jakarta. The BDRS can be assumed as a customer of PMI.

In this research, DKI Jakarta was chosen because it is the third province with the largest population nationally, indicating that the need for blood in the province is quite large. The greater the demand for blood needs, the PMI must also balance its operational activities to operate effectively and efficiently. One of the very important things is the role of blood distribution activities carried out by PMI. This blood distribution activity must be carried out quickly and precisely. If this activity is not carried out properly, there will be many impacts, including a decrease in the quality of the blood distributed, or it can even threaten the life of someone who needs blood supply at the hospital.

All the time, the blood distribution process, especially in Jakarta, has not used a planning system, so it cannot be defined which points will be sent blood according to the delivery route's order. Blood deliveries are carried out only based on the ambulance driver's preference to determine the route to be followed. In addition, the ambulance driver also considers the ambulance capacity during distribution activities so that the fulfillment of the demand for blood will be continued at the departure of another ambulance if the capacity is insufficient [5]. Based on that case, it could be interpreted that PMI does not have any routing procedure for distributing blood bags to each BDRS. Even though DKI Jakarta is one of the areas that has a high level of traffic congestion. So, it is necessary to manage schedules both distribution routes and travel time to distribute blood bags safely and quickly.

This research aims to determine the best route for blood distribution activities from PMI, Central Jakarta, to several BDRS in DKI Jakarta so that the route can guide ambulances when operating from one point to another until it reaches its destination. Determination of the points visited will produce an effective and efficient level of a route to be said to be the best route. The best route is expected to accelerate and minimize risks so that blood distribution can be carried out according to procedures, both in terms of speed and delivery accuracy. The data used to build this distribution model has been validated based on references from several literature studies due to limited data information in the field, so it is necessary to adjust the self-generated data in this research follow.

2. Method

a. Systematic Research

This research begins with conducting interviews and collecting data [1]obtained from the PMI Head Office, Central Jakarta. Furthermore, the data obtained is processed first. After that, they were modeling the existing problems. The model that has been built is then computed by coding using the AMPL software and Online IDE repl.it. The results obtained from the Nearest Neighbor (NN) algorithm recommendation will be the best route for blood distribution.

b. Research Steps

1. Literature Review

   The following are some sources of literature related to this research.

a) Research entitled Vehicle Routing Problem with the Nearest Neighbor Method Application conducted by Waluyo Prasetyo and Muchammad Tamyiz [6]. This research discusses the minimization of distance to reduce product distribution time, reduce fuel costs, save driver wages, and minimize total distribution costs.
b) Research with the title Vehicle Routing for Pick Up Problems with the Most Valuable Neighborhood and Nearest Neighbor Approaches to Goods Shipping Services carried out by Sudiana Wirasambada and Dwi Iryaning Handayani [7]. This research compares two methods, namely MVN-VRP and NN-VRP, in determining the best route. The result is that MVN-VRP produces the most optimal route.
c) Research with the title Proposed Planning for the Hanaang Gallon Water Distribution Route Using the Nearest Neighbor and Local Search Algorithm was conducted by Alfian Suyudi, Arif Imran, Susy Susanty [8]. This research discusses finding and determining the best route using two methods, namely Nearest Neighbor and Insertion Intra Route, which results in a difference of 13.1 km with a time saving of 39.3 minutes.

2. Data Collecting

   The data were collected by direct interviews with sources, namely the PMI Jakarta office and other relevant and accurate sources, used as data sets for data processing.

3. Data Processing

   The data that has been collected is then processed using Microsoft Excel, AMPL software, and Online IDE in repl.it.

4. Application of The Nearest Neighbor Algorithm

   The data is processed by applying the nearest neighbor algorithm.

5. Analysis

   The results will then be compared between the use of AMPL software with C++ programming using the nearest neighbor algorithm. From these two methods, it will be analyzed which method gives the most optimal value to be concluded.

6. Conclusions and Further Research

   The end of this research is to conclude the research that has been done and also to provide direction for further research.

c. Supporting Theory

The following are the theories used to support research.

1. Haversine Distance

   The Haversine formula theorem is an important equation in the field of navigation, to find the arc distance between two points on a sphere from longitude and latitude. This is a form of a special equation of spherical trigonometry, law of haversines, looking for the side and angle relationships of a triangle in a spherical plane [9,10].

$$d = 2r \times \arcsin\{\sqrt{\sin^2\left(\frac{Lat_1 - Lat_2}{2}\right) + \cos(Lat_1) \times \cos(Lat_2) \times \sin^2\left(\frac{Long_1 - Long_2}{2}\right)}\} \quad (i)$$

2. Vehicle Routing Problem (VRP)

   According to Bruce Golden, S. Raghavan, and Edward Wasil [11], Vehicle Routing Problem (VRP) is a problem in determining the best route. The route starts from the depot to the customer and returns to the depot. VRP can be a generalization of the Traveling

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Salesman Problem (TSP) because there are no limitations on capacity, depots, customers, and routes [12]. The purpose of VRP is to minimize distance, save distribution costs, reduce travel time, and reduce penalties that may be obtained. The following is a general VRP mathematical model.

Input

N : The collection of nodes where {1..n} is the customer and 0 is the depot

c_{ij} : The distance from node i to j where $(i,j) \in N$

K : The number of vehicle

Cap : The capacity of vehicle

d_i : The demand of customer i where $i \in N$

Decision Variables

$X_{ij} = \{^1_0$ is 1 if the node is arcs (i,j) the most optimal route appears, 0 if the opposite

u_i , u_j variable used for subtour elimination

Objective Function

Minimize $\sum_{i \in N} \sum_{j \in N} c_{ij} X_{ij}$ (ii)

Limitation

$\sum_{i \in N; i \neq j} X_{ij} = 1$ $\forall j \in N \backslash \{0\}$ (iii)

$\sum_{j \in N; i \neq j} X_{ij} = 1$ $\forall i \in N \backslash \{0\}$ (iv)

$\sum_{j \in N \backslash \{0\}} X_{0j} \leq K$ \ $\forall i \in N \backslash \{0\}$ (v)

$u_j - u_i + Cap * X_{ij} \leq Cap - d_i$ $i \neq j; \forall j \in N \backslash \{0\}; \forall i \in N \backslash \{0\};$ (vi)

$d_i \leq u_i \leq Cap$ $\forall i \in N \backslash \{0\}$ (vii)

$u_i \geq 0; u_j \geq 0$ $\forall i \in N, \forall j \in N$ (viii)

3. Nearest Neighbor (NN) Algorithm

According to Braysy and Gendreau [13], this method works by looking for the nearest point from the next to the last point on a route to be traversed. The most optimal feasible route is the route that will be applied as the best route. The following is the nearest neighbor algorithm steps.

1. Determine a vehicle with a start point from the depot;
2. Search for the nearest unvisited city from the last city where the vehicle is located;
3. Is the vehicle capacity still sufficient?
   a.) If still sufficient, continue the trip;
   b.) If not, go back to the depot and repeat the first step;
4. Are there any cities that have not been visited? If so, repeat the second step;
5. Return to the start point (depot).

d. Data Collecting

The data used in this research consist of various kinds of data as follows.

1. PMI and BDRS Location

   PMI head office distributes blood to 40 BDRS in DKI Jakarta, it represented in the following figure.

Figure 1 40 BDRS DKI Jakarta Location Points

2. The Demand Data of Blood Bag Need per Day per BDRS

   Table 2 shows the blood bag demand for each BDRS in DKI Jakarta. The blood bag demand is demand data per day.

Table 2 Blood Bag Demand Data for Each BDRS in One Distribution per Day

Node	City	District	BDRS	Blood Bags/Day
0	Central Jakarta	Senen	PMI DKI Jakarta **(Depot)**	
1	Central Jakarta	Senen	Cipto Mangunkusumo Hospital	2
2	Central Jakarta	Senen	Gatot Subroto Hospital	2
3	Central Jakarta	Senen	MH. Thamrin Hospital	2
4	Central Jakarta	Senen	St. Carolus Hospital	2
5	Central Jakarta	Tanah Abang	Dr. Mintohardjo Naval Hospital	6
6	Central Jakarta	Gambir	Budi Kemuliaan Hospital	4
7	Central Jakarta	Menteng	Cikini Hospital	3
8	Central Jakarta	Sawah Besar	Husada Hospital	5
9	Central Jakarta	Cempaka Putih	Jakarta Islamic Hospital	4
10	Central Jakarta	Kemayoran	Mitra Kemayoran Hospital	8
11	North Jakarta	Penjaringan	Atmajaya Hospital	13
12	North Jakarta	Penjaringan	Pantai Indah Kapuk Hospital	13
13	North Jakarta	Penjaringan	Pluit Hospital	13

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Node	City	District	BDRS	Blood Bags/Day
14	North Jakarta	Kelapa Gading	Gading Pluit Hospital	12
15	North Jakarta	Kelapa Gading	Mitra Kelapa Gading Hospital	12
16	North Jakarta	Koja	Koja Hospital	19
17	East Jakarta	Duren Sawit	Jakarta Islamic Hospital Pondok Kopi	22
18	East Jakarta	Pasar Rebo	Pasar Rebo Regional Public Hospital	16
19	East Jakarta	Pulo Gadung	Persahabatan Hospital	18
20	East Jakarta	Kramat Jati	Polri Hospital	14
21	East Jakarta	Kramat Jati	UKI Hospital	14
22	East Jakarta	Makasar	Haji Pondok Gede Hospital	16
23	East Jakarta	Ciracas	Harapan Bunda Hospital	18
24	East Jakarta	Jatinegara	Hermina Jatinegara Hospital	14
25	East Jakarta	Jatinegara	Premier Jatinegara Hospital	14
26	South Jakarta	Cilandak	Fatmawati Hospital	13
27	South Jakarta	Setiabudi	Jakarta Hospital	8
28	South Jakarta	Setiabudi	Medistra Hospital	8
29	South Jakarta	Setiabudi	MRCC Hospital	8
30	South Jakarta	Kebayoran Baru	Pertamina Hospital	12
31	South Jakarta	Kebayoran Lama	Pondok Indah Hospital	16
32	West Jakarta	Palmerah	Harapan Kita Women & Children Hospital	10
33	West Jakarta	Palmerah	Harapan Kita Cardiovascular Hospital	10
34	West Jakarta	Palmerah	Dharmais Cancer Hospital	10
35	West Jakarta	Palmerah	Pelni Petamburan Hospital	10
36	West Jakarta	Cengkareng	Cengkareng Hospital	24
37	West Jakarta	Kebon Jeruk	Graha Kedoya Hospital	13
38	West Jakarta	Kebon Jeruk	Siloam Kebon Jeruk Hospital	13
39	West Jakarta	Grogol Petamburan	Royal Taruma Hospital	12
40	West Jakarta	Grogol Petamburan	Sumber Waras Hospital	12

Source: [14]

3. The Data of PMI Head Office as a Depot
   Name : Indonesian Red Cross (Palang Merah Indonesia-PMI)
   Address : Jln. Kramat Raya No. 47 Jakarta 10450, Indonesia
   Number of Vehicle : 5 Ambulances
   Capacity of Vehicle : 400 Blood Bags

3. Results and Discussion

a. AMPL Software Completion Result

The computations are solved by AMPL software with Gurobi solver using Intel® Core™ i3-8130U Processor (2.20 GHz. up to 3.40 GHz. 4M Cache) with 4GB of RAM DDR4 as the first step. The initial stage is to write a mathematical model from VRP into .mod. After that, write down the data needed to get the solution on .dat. Then complete the program on the AMPL software.
The minimum total distance for vehicles to travel these routes is 116.15 km. Then, the route is as follows.

Route 1:
0 – 2 – 6 – 8 – 13 – 11 – 12 – 36 – 38 – 37 – 39 – 40 – 32 – 33 – 34 – 35 – 5 – 27 – 29 – 28 – 30 – 31 – 26 – 18 – 23 – 22 – 20 – 21 – 25 – 24 – 1 – 7 – 0.

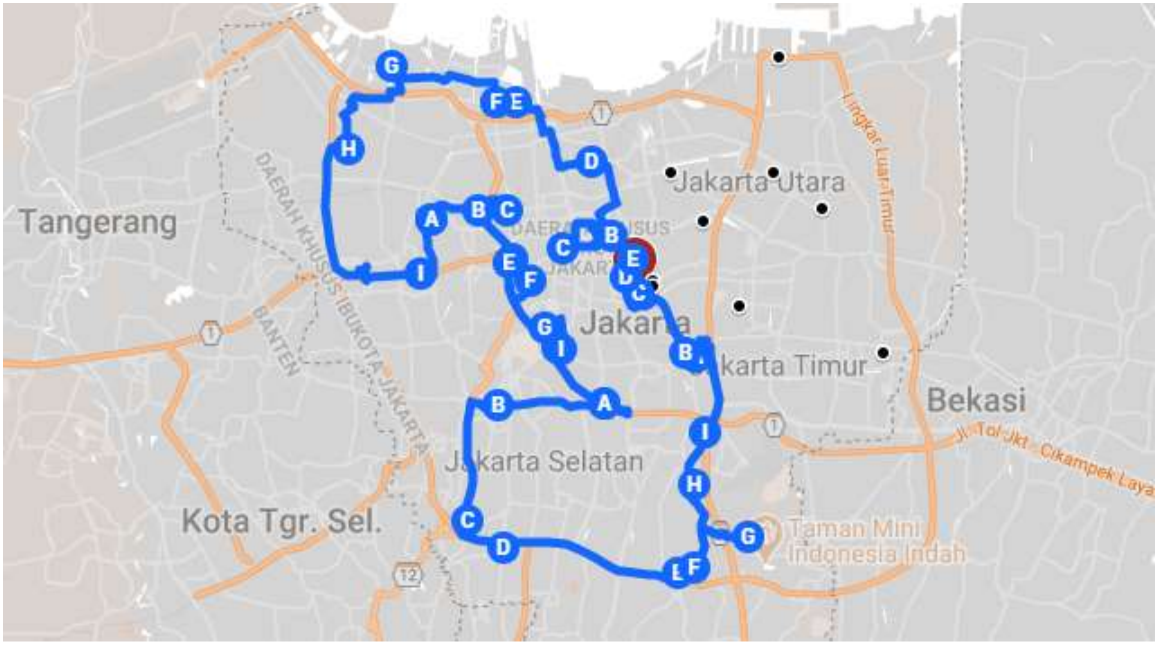

Figure 2 Route 1 for Blood Distribution Using AMPL

Route 1 Details:

PMI DKI Jakarta – Gatot Subroto Hospital – Budi Kemuliaan Hospital – Husada Hospital – Pluit Hospital – Atmajaya Hospital – Pantai Indah Kapuk Hospital – Cengkareng Hospital – Siloam Kebon Jeruk Hospital – Graha Kedoya Hospital – Royal Taruma Hospital – Sumber Waras Hospital –Harapan Kita Cardiovascular Hospital – Dharmais Cancer Hospital – Pelni Petamburan Hospital – Mintohardjo Naval Hospital – Jakarta Hospital – MRCC Hospital – Medistra Hospital – Pertamina Hospital – Pondok Indah Hospital – Fatmawati Hospital – RSUD Pasar Rebo Hospital – Harapan Bunda Hospital – Haji Pondok Gede Hospital – POLRI Hospital – UKI Hospital – Premier Jatinegara Hospital – Hermina Jatinegara Hospital – Cipto Mangunkusumo Hospital – Cikini Hospital – PMI DKI Jakarta.z

Route 2:

0 – 3 – 4 – 19 – 17 – 14 – 15 – 16 – 10 – 9 – 0.

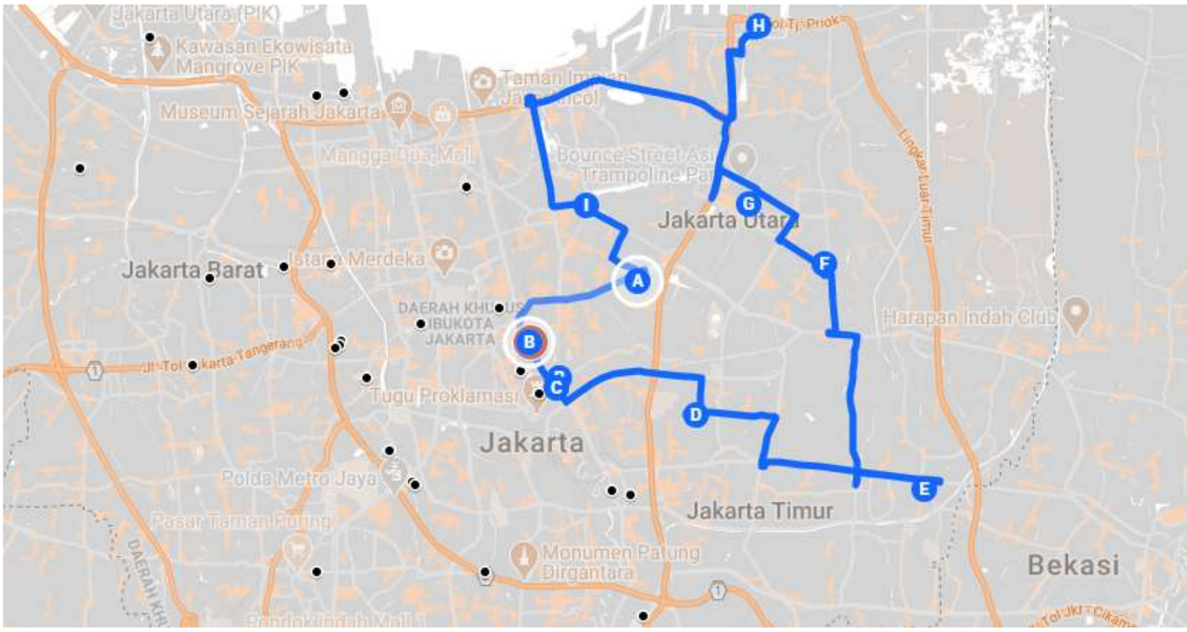

Figure 3 Route 2 for Blood Bag Distribution Using AMPL

Route 2 Details:

PMI DKI Jakarta – MH Thamrin Hospital – St. Carolus Hospital – Persahabatan Hospital – Jakarta Islamic Hospital Pondok Kopi – Gading Pluit Hospital – Mitra Kelapa Gading Hospital – Koja Hospital – Mitra Kemayoran Hospital – Jakarta Islamic Hospital – PMI DKI Jakarta.

b. C++ Programming - Nearest Neighbor Algorithm Result

Based on the NN algorithm that has been run using the C++ program, the minimum total distance for vehicles to travel these routes is 127.67 km and the optimal route is obtained as follows.

Route 1:

0 – 7 – 1 – 4 – 3 – 2 – 6 – 35 – 33 – 32 – 34 – 40 – 39 – 37 – 38 – 5 – 27 – 29 – 28 – 24 – 25 – 19 – 9 – 10 – 8 – 13 – 11 – 12 – 36 – 30 – 31 – 26 – 18 – 23 – 22 – 20 – 21 – 0.

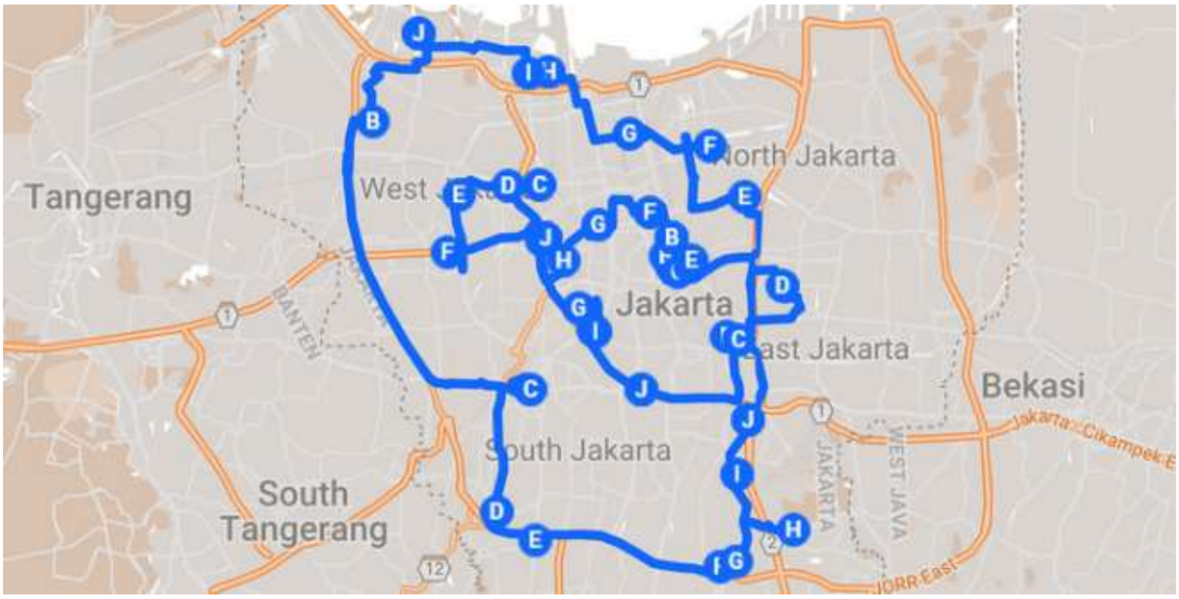

Figure 4 Route 1 for Blood Bag Distribution Using NN Algorithm

Route 1 Details:

PMI DKI Jakarta – Cikini Hospital – Cipto Mangunkusumo Hospital – St. Carolus Hospital – MH. Thamrin Hospital – Gatot Subroto Hospital – Budi Kemuliaan Hospital – Pelni Petamburan Hospital – Harapan Kita Cardiovascular Hospital – Harapan Kita Women & Children Hospital – Dharmais Cancer Hospital– Sumber Waras Hospital – Royal Taruma Hospital – Graha Kedoya Hospital – Siloam Kebon Jeruk Hospital – Mintohardjo Naval Hospital – Jakarta Hospital – Medistra Hospital – Hermina Jatinegara Hospital – Premier Jatinegara Hospital – Persahabatan Hospital – Jakarta Islamic Hospital – Mitra Kemayoran Hospital – Husada Hospital – Pluit Hospital – Atmajaya Hospital – Pantai Indah Kapuk Hospital – Cengkareng Hospital – Pertamina Hospital – Pondok Indah Hospital – Fatmawati Hospital – Pasar Rebo Regional Hospital – Harapan Bunda Hospital – Haji Pondok Gede Hospital – POLRI Hospital – UKI Hospital – PMI DKI Jakarta.

Route 2:

0 – 15 – 14 – 17 – 16 – 0.

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Figure 5 Route 2 for Blood Bag Distribution Using NN Algorithm

Route 2 Details:

PMI DKI Jakarta – Mitra Kelapa Gading Hospital – Gading Pluit Hospital – Jakarta Islamic Hospital Pondok Kopi – Koja Hospital - PMI DKI Jakarta.

c. Analysis

Table 3 Result Verification

Route	Vehicle Capacity (Blood Bags)	Total Distance (Km)	Demand Fulfilled (Blood Bags)
AMPL 1	400	78.19	346
AMPL 2	400	37.96	99
NN 1	400	88.07	380
NN 2	400	39.59	65

Based on the results in **Table 3**, the AMPL program produces 2 optimal routes and so does C++ program (using NN Algorithm). On route 1 of the AMPL program, vehicles cover a distance of 78.19 km with a fulfilled demand of 346 blood bags. This means that on route 1 the AMPL program can be served by an ambulance (the demand fulfilled is smaller than the vehicle capacity). Then, on route 2 of the AMPL program, the vehicle covered a distance of 37.96 km with a request that could be fulfilled by 99 bags of blood. So, on route 2 the AMPL program can be served by one ambulance because the demand that can be met is less than the capacity of the vehicle. Meanwhile, the NN Algorithm also generates 2 routes. On route 1 of the, vehicles cover a distance of 88.07 km with a fulfilled demand of 380 blood bags. This means that on route 1, the BDRS computed by NN Algorithm can be served by an ambulance (the demand fulfilled is smaller than the vehicle capacity). Then, on route 2 the vehicle covered a distance of 39.59 km with a request that could be fulfilled by 65 bags of blood. So, on route 2 that generated by NN Algorithm can be served by one ambulance because the demand that can be met is less than the capacity of the vehicle.

Based on this research, PMI is expected to form a department responsible for determining distribution routes. Instead of using driver preferences, the distribution route will use the NN algorithm always to be updated according to the blood bag demand in each BDRS every day. The implementation that can be done is the Google Maps application approach. Google Maps can provide the shortest route recommendations, either via toll roads or main roads, because this application can monitor traffic congestion, describing road conditions, such as crashes accidents, road works, and others.

4. Conclusion

Based on the results of research in solving the Vehicle Routing Problem (VRP) to optimize the distribution route of blood bags, it can be concluded:

1. The AMPL program produced 2 routes, each with a distance of 78.19 km and 37.96 km or a total of 116.15. Meanwhile, the demand for uninhabitable amounted to 346 and 99 blood bags respectively. Then, in the NN Algorithm, the total distance traveled by the vehicle for 2 routes are 88.07 km and 39.59 km with demand fulfilled 380 and 65 blood bags.
2. The route produced by the AMPL program is shorter than the route produced by the NN Algorithm. Therefore, that when the two programs are compared, the AMPL program produces the most optimal route in minimizing vehicle mileage. This means that there will be savings in mileage and can also maintain the quality of blood, given that blood is included as perishable goods.
3. This research can be developed for sustainability research using a simulated annealing algorithm with an ideal computation time. The results obtained can be more accurate, and the research analysis can use aspects of cost savings incurred during blood distribution activities.

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