Journal of Industrial Engineering and Halal Industries (JIEHIS) P-ISSN 2722-8150
Vol. 4 No. 1 June 2023 E-ISSN 2722-8142

A Tabu Search Algorithm for Optimization of Blood Distribution Routes

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Abstract

PMI Blood Transfusion Unit (UTD PMI) is an agency that provides or a health service agency that organizes blood donation and blood supply. The observations and interviews showed that some existing cases were not carried out immediately and accurately, and there was no distance to align the duration with blood cells. The formation of blood distribution routes only stems from the highest number of requests and the delay in the distribution in several hospitals. Therefore, it is necessary to determine vehicle routes to meet demand due to the limited number of vehicles. The distribution time limit is another obstacle in the distribution process due to delays in delivering blood products from UTD to hospitals or hospital blood banks. In this study, the CCVRPTW solution was determined using a metaheuristic algorithm, namely the Tabu Search algorithm, to minimize blood distribution routes and distances at UTD PMI Pekanbaru. The solution for blood distribution is solved using a programming language through MATLAB software based on the Tabu Search algorithm. Based on the study results, the route 0-1-14-8-18-6-2-17-11-10-4-3-15-9-5-7-16-19-12-13-0 with a distance of 55, 9 KM in 67.1 Minutes. The initial distribution route is 0-1-2-6-5-4-3-7-17-8-13-11-12-14-16-15-18-9-10-19-0 with a distance of 130.7 KM in 156.8 minutes. UTD PMI uses one coolbox with 100 bags of blood capacity, but there is a delay because it only uses one vehicle. The optimized route is divided into two routes: car 1 has a route of 0-1-14-8-18-6-0 with a total distance of 9.2 KM, and car 2 has a route of 0-2-17-11-10-4 -3-15-9-5-7-16-19-12-13-0 with a total distance of 50.6 KM.

Keywords : Route; Optimization; Tabu Search Algorithm; Blood; Distribution

INTRODUCTION

Blood is a body tissue fluid that transports oxygen to cells throughout the human body. Blood is an indispensable resource for cancer treatment, organ transplantation, accident victims and major surgery. However, these resources are classified as rare, and so far, no product can replace blood and its derivative products (Liu et al., 2020). Therefore, as a substitute for and overcoming all diseases that require blood, these resources are obtained from human donations. These donations may not necessarily meet the requirements for donating blood. Research shows that 95% of the donor population is not eligible to donate (Katsaliaki, 2008).

The blood supply chain is a complex system involving different interrelated parameters and stakeholders such as hospitals, blood banks and donors. There are three types of blood service institutions in Indonesia, namely PMI UTD (Indonesian Red Cross Blood Transfusion Unit), Hospital UTD (Hospital Blood Transfusion Unit) and BDRS (Hospital Blood Bank) (Rayendra, 2019). The difference between UTD and BDRS is that BDRS only gets a supply of blood bags from UTD PMI and does not provide a blood transfusion system from donors. UTD PMI is a unit that offers blood bags to meet the demands of hospitals that only have a BDRS system. This research was conducted at UTD PMI Pekanbaru City, which has many requests for blood from BDRS. The object of this research is the blood bag.

The agency does not have a proper schedule for delivering blood bags. So, many patients are not helped due to a lack of blood supply in several hospitals in Pekanbaru City. In addition, every hospital often experiences stockouts of blood bags due to a mismatch between demand and supply. Other studies support this problem that PMI has issues in the distribution process of blood bags, so many recipients have difficulty getting blood (Puji et al., 2020). Then, another study stated that the main problem of the blood supply chain system is that the number of donors from time to time has decreased compared to the increasing demand for blood products (Reynolds et al., 2001). Therefore, this research is very relevant to the study because the key to its success is in the proper and optimal distribution process, even if there is a decrease in supply from donors compared to the demand for blood bags. Most of these studies mention blood supply chain research because there are human processes in it.

Table 1. Blood Demand from Several Hospitals.

No	Hospitals	Demand Fulfilled	Demand Unfulfilled
1	RSIA Eria Bunda	1299	84
2	RS Islam Ibnu Sina	3786	109
3	RS Prima	227	162
4	RS Sansasi	800	70

Determination of distribution routes needs to be done at UTD PMI, considering a large number of requests for blood from Hospital Blood Banks in the Pekanbaru area. The decision of a good vehicle route needs to be made to meet demand given the limited number of vehicles, so UTD PMI must consider the number of requests for each hospital. The distribution time limit is another obstacle in the distribution process due to delays in delivering blood products from UTD to hospitals or hospital blood banks. This problem is known as the Vehicle Routing Problem. One variant of VRP that considers vehicle capacity and delivery time is the Capacitated Closed Vehicle Routing Problem with Time Windows (CCVRPTW)(Paolo, 2006). CCVRPTW problems can be solved by using heuristic algorithms or metaheuristic algorithms. Metaheuristics create a more maximal solution and faster computational duration than exact and heuristic methods. In this study, the CCVRPTW solution was determined using a metaheuristic algorithm, namely the Tabu Search algorithm, to minimize blood distribution routes and distances at UTD PMI Pekanbaru. The basic concept of Tabu Search is to determine a solution at each iteration to find the best solution without being trapped in the local optimum solution during the iteration (Gmira et al., 2021). This method explores the solution space by moving each iteration from the key to the best solution in a subset of its environment (Cordeau et al., 1997).

METHODS

This research uses the Tabu Search Algorithm to solve the closed vehicle route problem with time windows (CCVRTW) in determining the optimal route and distribution distance at UTD PMI Pekanbaru. CCVRTW is a variant of VRP (vehicle routing problem) which considers vehicle capacity and distribution period (Prasetyo et al., 2018). The main purpose of this study is to determine the estimated blood demand and, based on forecasting, determine the optimal distribution route and distance at UTD PMI Pekanbaru City. This study was carried out by collecting data studying literature, observation and interviews. The resolution of CCVRPTW with the tabu search algorithm is as follows:

1. Determination of estimated blood demand
   a. Determining the forecasting of blood demand using the forecasting method
   b. Determining forecasting errors
   c. Determine the best method by looking at the smallest MSE (Mean Square Error) value

2. Determination of blood distribution route and distance
   Calculations using a programming language coded by MATLAB. The following steps are carried out:
   a. Determine the initial solution and set it as the optimum solution
   b. Determine alternative solutions, namely by move
   c. Choose the best solution among the alternative solutions in step 2. If the alternative solution is listed in the tabu list, the alternative solution will not be evaluated unless it meets the aspiration criteria.
   d. Choose the optimum solution. In step 3, if the value of the best solution is less than the value of the previous optimum solution, the best solution becomes the new optimum solution. If not, a diversification process is carried out.
   e. Updating the tabu list to include a new optimum solution
   f. If the termination criteria are met, it stops, and the optimum solution is obtained. If not, return to step 2.

3. Determination of the number of Vehicle
   a. Determine the number of routes for each vehicle from UTD to 19 hospitals based on coolbox capacity
   b. Calculating the distance of each vehicle route
   c. Comparing the route and distance distribution of current and proposed conditions

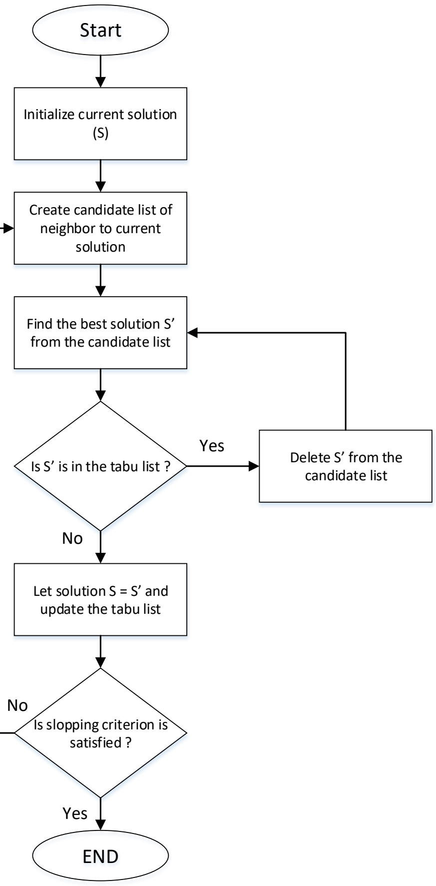

Figure 1. Flowchart of Tabu Search (Hao, Wang, Wu, Boriboonsomsin, & Barth, 2017)

RESULT AND DISCUSSION

1. Determination of Estimated Demand Based on Forecasting

Forecasting is the art and science of predicting future events (Heizer & Barry, 2015). Determination of the number of blood requests at UTD PMI measures the blood demand level in the future. Determination of blood demand is done by forecasting method. The demand data consisting of 19 hospitals were plotted for analysis, and the appropriate forecasting model was selected. The plot of Demand for Blood at Rumah Sakit Ibnu Sina shown in figure 1.

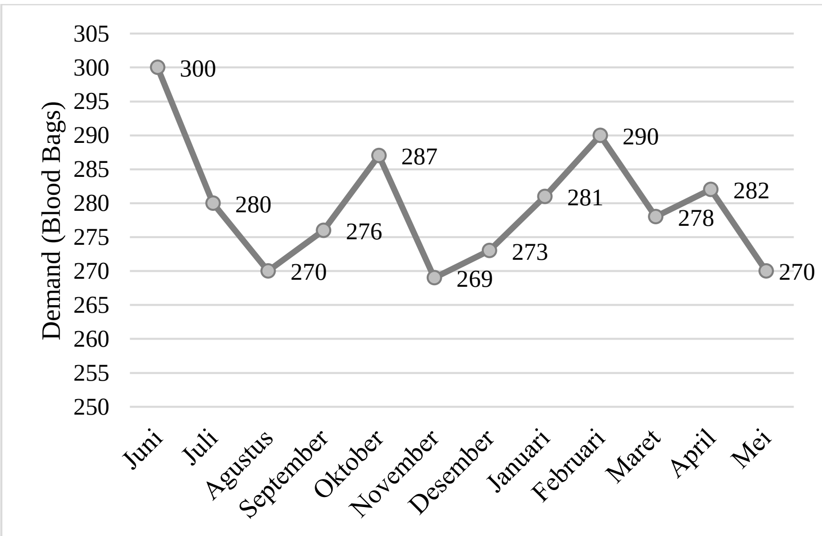

Figure 2. The plot of Demand for Blood at Rumah Sakit Ibnu Sina

Based on the data plot that has been done, the data forms a fluctuating horizontal pattern, meaning that the data pattern is seasonal. Therefore, the appropriate model is the time series analysis, forecasting model. Some of the models used are Simple Average (SA), Moving Average (MA), Single Exponential Smoothing (0.5) (SES), and Adaptive Exponential Smoothing (AES). From the results of forecasting the demand for blood, the best forecasting method is determined by choosing the smallest MSE (Mean Square Error) value, as shown in table 2.

Table 2. MSE Results Based on Each Forecasting Method

No.	Hospital	MSE (Mean Square Error)			
		SA	MA	SES	AES
1	RSUD Arifin Ahmad	23106,47	19755,00	24352,64	24161,93
2	RS Islam Ibnu Sina	123,35	120,75	131,72	131,76
3	Eka Hospital	37,79	30,13	31,94	31,14
4	RS Awal Bros Panam	225,97	142,55	248,90	220,47
5	RS Awal Bros Sudirman	2,66	4,00	3,28	3,36
6	RS Santa Maria	5,67	8,35	6,49	5,20
7	RS Syafira	5,04	6,67	5,32	4,58
8	RS Bina Kasih	3,77	5,82	5,09	3,48
9	RS Mesra	0,50	0,80	0,59	0,59
10	Aulia Hospital	1,91	2,67	2,09	1,77
11	RS Prima	1,44	2,27	1,66	1,49
12	RS PMC	1,38	1,67	1,32	1,31
13	RSUD Petala Bumi	3,15	4,67	4,06	3,54
14	RS Polda Riau	1,84	2,02	1,71	1,53
15	RS Sansani	1,81	1,87	1,77	1,67
16	RS Tabrani	2,05	2,47	2,05	1,83
17	RS Eria	5,17	10,10	6,65	6,89
18	RS TNI AD	0,50	0,80	0,59	0,59
19	RSIA Zainab	1,38	1,67	1,32	1,31

Based on the smallest MSE value calculation, the simple average method was obtained at Rumah Sakit Awal Bros Sudirman, Rumah Sakit Mesra, Rumah Sakit Prima, Rumah Sakit Petala Bumi, Rumah Sakit Eria, Rumah Sakit TNI AD. Then the moving average method at Arifin Ahmad, Rumah Sakit Ibnu Sina Islamic, Eka Hospital, Rumah Sakit Awal Bros Panam. While the adaptive exponential smoothing method at Rumah Sakit Santa Maria, Rumah Sakit Syafira, Rumah Sakit Bina Kasih, Aulia Hospital, Rumah Sakit PMC, Rumah Sakit Polda Riau, Rumah Sakit Sansani, Rumah Sakit Tabrani, Rumah Sakit Zainab. The best forecasting results for each hospital based on the smallest MSE are shown in table 3.

Table 3. Blood Demand per Day

No	Hospital	Demand/Day	Demand/Year
1	RSUD Arifin Ahmad	78	28080
2	RS Islam Ibnu Sina	9	3312
3	Eka Hospital	12	4158
4	RS Awal Bros Panam	7	2628
5	RS Awal Bros Sudirman	12	4325
6	RS Santa Maria	10	3612
7	RS Syafira	9	3250
8	RS Bina Kasih	3	1071
9	RS Mesra	2	724
10	Aulia Hospital	2	723
11	RS Prima	2	714
12	RS PMC	3	1061
13	RSUD Petala Bumi	3	1072
14	RS Polda Riau	2	720
15	RS Sansani	3	1069
16	RS Tabrani	2	722
17	RS Eria Bunda	5	1806
18	RS TNI AD	2	724
19	RSIA Zainab	3	1061

2. Determination of Routes and Distribution Distances Using the Tabu Search Algorithm

Before determining the route and distribution distance, required distance data is obtained from the google maps website, then converted into a distance matrix. While the travel time is obtained from the following formulation:

$$Travel\ Time = \frac{Distance\ (Km)}{Speed\ (\frac{Km}{hours})}\ x\ 100\% \quad (1)$$

a. Determining Initial Solution

Calculations using MATLAB software. The first step is to select and determine the initial solution as the optimum solution in the 0th iteration using the nearest neighbor, which will produce a blood bag distribution route. The stages for establishing the distribution route are as follows.

1. The first stage is to determine the closest point to the depot and find the location of the hospital that has the shortest distance from the depot.
2. The second stage is to choose the closest location after the initial destination location is hospital 19.
3. The third stage is to repeat the second stage until all locations are connected to other locations to form a route.
4. The fourth stage is when all customers have been visited, then the algorithm has ended.

The initial solution is obtained. Namely, the path 0-1-14-19-16-7-5-9-15-3-4-10-11-17-2-6-18-8-13-12, and the solution will automatically be included in the tabu list at the 0th iteration as well as the initial optimum solution.

b. Determining Alternative Solutions

In this step, determine the next iteration and find a replacement solution that does not violate the tabu criteria. A replacement settlement is obtained by changing the position of 2 points or the dealer based on the indicator. In looking for alternative solutions, several actions can be taken, namely the part of the route points in the swap (swap), flip (reverse) and slide (slide). The index number is 171.

In iteration 0 obtained tabu list 0 1 14 19 16 7 5 9 15 3 4 10 11 17 2 6 18 8 13 12, then the alternative solution obtained using the swap action is

a. If the index (1) of the 1st point position is exchanged for the 2nd point position, the 1st alternative path is obtained: 1 0 14 19 16 7 5 9 15 3 4 10 11 17 2 6 18 8 13 12.
b. If the index (2) of the 1st point position is exchanged for the 3rd point position, the 2nd alternative path is obtained: 14 1 0 19 16 7 5 9 15 3 4 10 11 17 2 6 18 8 13 12.
c. If the index (3) of the 1st point position is exchanged for the 4th point position, the 3rd alternative path is obtained: 19 1 14 0 16 7 5 9 15 3 4 10 11 17 2 6 18 8 13 12.
d. If the index (4) of the 1st point position is exchanged for the 5th point position, the 4th alternative path is obtained: 16 1 14 19 0 7 5 9 15 3 4 10 11 17 2 6 18 8 13 12.
e. If the index (5) of the 1st point position is exchanged for the 6th point position, the 5th alternative path is obtained: 7 1 14 19 16 0 5 9 15 3 4 10 11 17 2 6 18 8 13 12.

And so on until the index is 171. Choosing the best solution from alternative solutions can be done if the value of the best solution in the previous step is smaller than the initial optimum solution. The best optimum solution obtained is chosen as the new optimum solution.

c. Updating Tabu List

The Tabu Search algorithm process is repeated starting from step 2 and will stop when the termination criteria are met. Obtained the optimal solution using the Tabu Search algorithm. The following code is used in the calculation of the tabu search algorithm. From the processing, the path results are 0-1-14-8-18-6-2-17-11-10-4-3-15-9-5-7-16-19-12-13-0 with a total distance of 55.9 KM. In the distribution of blood, the proposed optimization results generate a reduction in mileage.

d. Determination of the Number of Vehicles

It is distributing blood to 19 UTD PMI hospitals using a vehicle in the form of a pickup. UTD blood distribution uses a coolbox to transport blood because of the blood's nature, which is easily damaged (Beliën & Forcé, 2012). UTD PMI Pekanbaru operates one coolbox with a capacity to load 100 bags of blood to send blood to 19 hospitals, but delays often occur because it only uses one vehicle.

After calculating the distribution route determination, increasing the number of fleets is necessary to minimize distribution time. The proposal uses two vehicles, and the distribution route is divided into two based on the number of requests and the capacity of the coolbox. Car 1 has route 0-1-14-8-18-6-0 with a total request of 95 blood bags, and car 2 has path 0-2-17-11-10-4-3-15-9-5-7 -16-19-12-13-0 with a total request of 74 blood bags.

e. Comparison of Route and Distance Distribution of Current and Proposed Conditions

In the distribution of blood, the proposed optimization results generate a reduction in mileage. The proposed distribution route has two routes. For vehicle 1, the route is 0-1-14-8-18-6-0 with a total distance of 9.2 KM and a travel time of 11.04 minutes. For vehicle 2, the path is 0-2-17-11-10-4-3-15-9-5-7-16-19-12-13-0 with a total distance of 50.6 KM and a travel time of 60.72 Minutes. So the total distance traveled is 59.8 KM. Meanwhile, the current route used by UTD PMI has a total mileage of 130.7 KM. The reduction in distance that occurs is 70.9 KM or 41%.

Table 4. Comparison of the Initial Route with the Proposed Distribution Route

Routes	**Improvement**	**Total Distance (Km)**	**Total travel time (Minutes)**
Initial Route	0-1-2-6-5-4-3-7-17-8-13-11-12-14-16-15-18-9-10-19-0	130,7	156,8
proposed route			
Vehicle 1	0-1-14-8-18-6-0	9,2	11,04
Vehicle 2	0-2-17-11-10-4-3-15-9-5-7-16-19-12-13-0	50,6	60,72

CONCLUSION

This study provides a solution for CCVRPTW using the tabu search algorithm. Determination of estimated blood demand based on forecasting determines future blood demand. Forecasting results at 19 hospitals obtained varied requests according to the chosen method by looking at the smallest MSE value. The methods used in this study in forecasting the demand for blood bags are simple average, moving average, single exponential smoothing (0.5) and adaptive exponential smoothing.

Based on calculations using the tabu search algorithm, it can be a solution to the problem of distribution routes at UTD PMI, namely the 0-1-14-8-18-6-2-17-11-10-4-3-15-9-5-7-16-19-12-13-0 path. Meanwhile, the proposed fleet has two vehicle routes, vehicle 1, route 0-1-14-8-18-6-0, with a total request of 95 bags of blood and car 2 having route 0-2-17-11-10-4-3 -15-9-5-7-16-19-12-13-0 with a total request of 74 blood bags. The results obtained from the processing carried out are more optimal than the current route, with the distance reduction that occurs at 70.9 KM or 41%.

The limitations of this study assume that the demand for blood is deterministic, where the demand is considered constant and can be predicted with certainty. However, this study recognizes the need for further research with stochastic modeling, which considers fluctuations and uncertainties in blood demand. It is hoped that future research will use stochastic models to gain a deeper understanding of the variability of blood demand and identify more effective management strategies for dealing with this uncertainty.

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