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# Evaluation Of Blood Distribution Route in The Downstream Supply Chain of The Indonesian Red Cross Jember

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## Abstract

The PMI Blood Donor Unit (UDD) throughout Indonesia, including the UDD PMI Jember, has an important role in distributing blood to various hospitals quickly and precisely. Therefore, distribution route efficiency is needed so that the blood delivery process can be carried out more quickly, on time, and cost-effectively. This study aims to evaluate the blood distribution routes of PMI Jember using the Clarke-Wright Savings Algorithm (CWS) and Nearest Neighbor (NN). The analysis was conducted by comparing travel distance and operational costs before and after optimization. The findings show Clarke-Wright Savings algorithm demonstrated a higher efficacy than the Nearest Neighbor method on the 20th of November 2024, with cost savings ranging from 48% to 67% in each shift, when servicing seven hospital locations. Conversely, the Nearest Neighbor method exhibited superior efficiency on the 21st of November 2024 when the number of destination locations increased to 13 hospitals. The efficiency comparison indicates that the number of distribution destination locations has a significant impact on the performance of both methods.

**Keywords:** Clarke-Wright Savings Algorithm, Nearest Neighbor, Route Optimization, Blood Distribution.

## 1. Introduction

The availability of sufficient blood in a country is an important matter that cannot be ignored. In Indonesia, the availability of blood is fulfilled through blood services conducted by the government and coordinated with the Indonesian Red Cross through blood donor units encompasses mobilizing and preserving blood donors, providing and processing blood and/or blood components, and distributing blood and/or blood components to health service facilities.

As a perishable product, blood requires a temperature-controlled supply chain to maintain its quality. Minister of Health Regulation No. 91/2015 delineates the procedures for the distribution of blood, requiring the implementation of a closed system that maintains standards of quality and safety, excluding the involvement of external parties. This regulation also encompasses the implementation of a cold chain method, which involves the maintenance of optimal temperatures for blood and blood components to ensure their viability and potability. The regulation applies to all PMI units in Indonesia, including PMI Jember. Apart from that, blood must be distributed in a timely manner and in accordance with procedures to ensure that its quality is maintained.

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PMI Jember encounters challenges in terms of route effectiveness due to the non-implementation of distribution routes, which hinders the production of optimal routes and consequently results in increased mileage. This has the potential to result in waste during the distribution process of blood. In accordance with the research by Heitmiller *et al*. (2010), 87% of red blood cell waste is attributed to temperatures that are substandard during storage and transportation. An extended duration of transportation can also result in elevated fuel consumption, which can lead to increased fuel expenditures. Research on PMI Jember Regency has been studied by Safitri *et al*. (2022), who discuss the application of the continuous review system method to blood inventory control by PMI Jember Regency. However, this research focuses on blood inventory control and does not mention the optimization of blood distribution at PMI Jember Regency.

Previous research on blood distribution, such as that conducted by Putratama et al. (2020), employed the Fuzzy Sugeno method to determine the optimal path at PMI Bandung City, yielding two optimal paths. However, this method necessitates a sophisticated design of rules and membership functions and is not tailored to the Vehicle Routing Problem (VRP) specifically. In a similar study, Hidayatullah et al. (2024) applied Dijkstra's algorithm to determine the shortest route in PMI Deli Serdang City, resulting in a route with a total distance of 2.1 kilometers in 5 minutes. However, this study focused exclusively on routes between two points and did not consider vehicle capacity or overall route optimization. In contrast, the present study focuses on VRP by considering vehicle capacity and overall route optimization.

A method that can be applied when attempting to solve the Vehicle Routing Problem (VRP) and optimize distribution routes is the Clarke-Wright Savings Algorithm. The Clarke-Wright Savings algorithm is a method in the form of an algorithm applied to the vehicle route problem. It involves exchanging routes at each step to achieve a more optimal set of routes (Kurniawan and Nugroho, 2022). However, the Clarke-Wright Savings Algorithm method determines the route based on the maximum savings by taking into account the vehicle's capacity. This method does not consider the order of the distance between locations, resulting in routes that tend to be disordered. In contrast, blood is a perishable product with a limited storage life. Therefore, it must be distributed promptly to maintain its quality until it reaches the hospital. Consequently, a route analysis employing the Nearest Neighbor method is conducted with the objective of optimizing the delivery process to ensure the blood arrives in a timely and optimal condition.

Thus, this research is expected to prove the effectiveness of Clarke-Wright Savings Algorithm and Nearest Neighbor in evaluating distribution routes and providing effective and efficient solutions for blood distribution in the downstream supply chain of PMI Jember Regency to improve more optimal blood services.

## 2. Research Method

### 2.1 Research Design

The present study was conducted using a quantitative descriptive method, which entails the utilization of numerical data.

### 2.2 Source of Data

The data utilized in this investigation is of a secondary nature. The secondary data sources utilized in this study were obtained from UDD PMI Jember.

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### 2.3 Data Collection Techniques

Data collection in this study involved secondary data acquisition through multiple methods. Interviews were conducted with UDD PMI Jember to gain an understanding of current blood distribution patterns and constraints. These interviews served as supplementary information, as PMI currently does not implement a specific distribution optimization method. Additionally, the blood distribution process consists of two types, regular distribution and emergency distribution. Direct observation was performed to analyze real-world distribution practices, while documentation of UDD PMI Jember's blood jet logbook provided essential data on hospital delivery records. The logbook functions as a transport record, detailing which hospitals received blood deliveries, the number of blood bags requested, and the number of samples received. Since the logbook data was already structured, no specific processing techniques were required. The data was simply compiled and summarized for analysis. For distance calculations**,** GIS and Excel-based software were utilized to determine the travel distances between distribution points.

### 2.4 Data Analysis Method

1. Distance Matrix Calculation
   The distance matrix represents travel distances between locations. In this study, it is calculated using GIS (Geographic Information System) software
2. Savings Matrix Calculation
   Savings for each location pair is determined using:

   $$S(i,j) = C_{0i} + C_{0j} - C_{ij}$$

   $C_{0i}$: Distance from depot to location i

   $C_{0j}$: Distance from depot to location j

   $C_{ij}$: Distance between locations i and j

   Savings values are sorted in descending order.
3. Route Merging
   Routes are merged based on the highest savings value while considering vehicle capacity.
4. Fuel Cost Calculation
   Fuel cost is calculated based on vehicle fuel consumption rates for UDD PMI Jember blood distribution:
   1. Motors

      $$\text{Fuel cost} = \frac{Total\ distance}{35} \times fuel\ price$$

   2. Car

      $$\text{Fuel cost} = \frac{Total\ distance}{12{,}5} \times fuel\ price$$

5. Nearest Neighbor Analysis
   The Nearest Neighbor method optimizes blood distribution routes by minimizing travel distance. As a refinement of the Clarke-Wright Savings Algorithm, this method selects the closest location as the next destination and repeats the process until all locations are visited.

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## 3. Data Collecting

UDD PMI Jember is responsible for the distribution of blood to 13 hospital locations throughout the Jember district. The hospital data is presented in Table 1.

**Table 1. Hospitals Data of UDD PMI Jember**

| Code | Name | Adress |
|---|---|---|
| 0 | UDD PMI | Srikoyo Street No.115, Krajan, Patrang, Kecamatan Patrang, Kabupaten Jember, Jawa Timur |
| 1 | RSD dr. Soebandi | DR. Soebandi Street No.124, Krajan, Patrang, Kec. Patrang, Kabupaten Jember, Jawa Timur 68111 |
| 2 | RS Paru | Nusa Indah Street No.28, Krajan, Jemberlor, Kec. Patrang, Kabupaten Jember, Jawa Timur 68118 |
| 3 | RSD Kalisat | MH. Thamrin Street No.31, Dusun Krajan, Ajung, Kec. Kalisat, Kabupaten Jember, Jawa Timur 68193 |
| 4 | RS Perkebunan Jember Klinik | Bedadung Street No.2, Kp. Using, Jemberlor, Kec. Patrang, Kabupaten Jember, Jawa Timur 68118 |
| 5 | RSU Kaliwates | Diah Pitaloka Street No.4a, Kaliwates Kidul, Kaliwates, Kec. Kaliwates, Kabupaten Jember, Jawa Timur 68131 |
| 6 | RS Citra Husada | Teratai Street No.22, Gebang Timur, Gebang, Kec. Patrang, Kabupaten Jember, Jawa Timur 68117 |
| 7 | RS Bina Sehat | Jayanegara Street No.7, Kaliwates Kidul, Kaliwates, Kec. Kaliwates, Kabupaten Jember, Jawa Timur 68131 |
| 8 | RSD Balung | Rambipuji, Kebonsari, Balung Lor, Kec. Balung, Kabupaten Jember, Jawa Timur 68161 |
| 9 | RSU Srikandi | KH Agus Salim Street No.20, Tegal Besar Kulon, Tegal Besar, Kec. Kaliwates, Kabupaten Jember, Jawa Timur 68132 |
| 10 | Siloam Hospitals | Gajah Mada Street No.104, Kb. Kidul, Jember Kidul, Kec. Kaliwates, Kabupaten Jember, Jawa Timur 68131 |
| 11 | RS Baladhika Husada (DKT) Jember | Panglima Besar Sudirman Street No.45, Pagah, Jemberlor, Kec. Patrang, Kabupaten Jember, Jawa Timur 68118 |
| 12 | RSU Universitas Muhammadiyah Jember | Wolter Monginsidi Street No.91, Area Sawah/Kebun, Kranjingan, Kec. Sumbersari, Kabupaten Jember, Jawa Timur 68126 |
| 13 | RS Utama Husada Ambulu | Manggar Street No.134, Tegalsari, Kec. Ambulu, Kabupaten Jember, Jawa Timur 68172 |

Source: PMI Jember’s Secondary Data, 2024

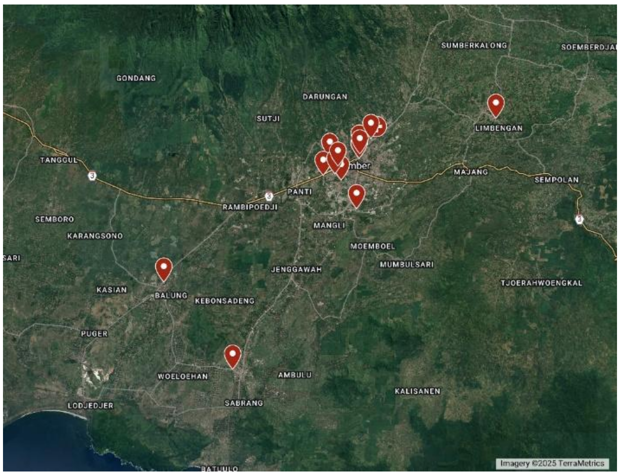


**Fig 1. Distribution map of hospital locations**

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The distribution of blood at UDD PMI Jember is divided into three shifts on a daily basis. A review of the data collected reveals that the distribution process currently exhibits several repetitive travel routes, as illustrated in table 2 and table 3, which contain blood distribution data from 20th & 21st of November 2024. Presently, the determination of distribution routes and stop locations at UDD PMI Jember is exclusively determined by the distribution driver.

Table 2. Actual Distribution Route on 20th of November 2024

| **Date** | **Shift** | **Routes** | **Total Distance** | **Total Demand (Blood bags)** | **Total Supply (Blood samples)** |
|---|---|---|---|---|---|
| 20/11/2024 | I | 0 – 2 – 1 – 11 – 0 | 11,1 km | 4 | 1 |
| | | 0 – 1 – 0 | 2,6 km | - | 1 |
| | | 0 – 4 – 0 | 7,80 km | 7 | - |
| | | 0 – 11 – 4 – 1 – 0 | 9 km | 7 | 7 |
| | | 0 – 1 – 0 | 2,6 km | - | 1 |
| | | 0 – 10 – 0 | 15 km | - | 1 |
| | Total | | 48,1 km | 18 | 11 |
| | II | 0 – 4 – 11 – 0 | 7,9 km | 2 | - |
| | | 0 – 11 – 4 – 1 – 0 | 9 km | 6 | - |
| | | 0 – 1 – 0 | 2,6 km | 2 | - |
| | | 0 – 6 – 5 – 11 – 2 – 4 – 1 – 0 | 23,4 km | 1 | 15 |
| | | 0 – 2 – 5 – 0 | 16,7 km | 5 | - |
| | Total | | 59,6 km | 16 | 15 |
| | III | 0 – 11 – 1 – 9 – 0 | 18,7 km | 8 | 2 |
| | | 0 – 1 – 11 – 2 – 5 – 0 | 17,4 km | 6 | 3 |
| | Total | | 36,1 km | 14 | 5 |

Source: PMI Jember's Secondary Data, 2021

**Table 3. Actual Distribution Route on 21st of November 2024**

| Date | Shift | Routes | Total Distance | Total Demand (Blood bags) | Total Supply (Blood samples) |
|---|---|---|---|---|---|
| 21/11/2024 | I | 0 – 4 – 6 – 2 – 0 | 14,7 km | 3 | - |
| | | 0 – 6 – 0 | 14,2 km | 3 | - |
| | | 0 – 8 – 0 | 53,8 km | 2 | - |
| | | 0 – 13 – 0 | 62,4 km | 1 | - |
| | Total | | 145,1 km | 9 | - |
| | II | 0 – 4 – 11 – 5 – 6 – 0 | 19,4 km | 10 | - |
| | | 0 – 4 – 5 – 10 – 0 | 17,9 km | 10 | - |
| | | 0 – 9 – 7 – 0 | 18 km | - | 2 |
| | | 0 – 1 – 7 – 12 – 11 – 0 | 27 km | 14 | 6 |
| | | 0 – 11 – 7 – 0 | 15,2 km | 3 | 1 |
| | | 0 – 3 – 0 | 30 km | 3 | - |
| | Total | | 127,5 km | 40 | 9 |
| | II | 0 – 1 – 0 | 2,6 km | 3 | - |
| | | 0 – 11 – 4 – 10 – 7 – 5 – 9 – 12 – 0 | 18,8 km | 11 | - |
| | | 0 – 11 – 0 | 6,8 km | 2 | - |
| | | 0 – 1 – 0 | 2,6 km | 2 | - |
| | Total | | 30,8 km | 18 | - |

Source: PMI Jember's Secondary Data, 2024

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The distribution process, which spanned two days, was executed through the utilization of two motorcycles in each shift. The cost of distribution was determined by a fuel consumption of 35 kilometers per liter, adjusted for a Pertalite price of Rp10,000 per liter. The following section presents a detailed breakdown of the distribution cost per day and the total cost over the two-day period.

**Table 4. Fuel Cost Data by UDD PMI Jember**

| Date | Transportation type/Capacity | Shift | Distance (km) | Fuel Price (Rp/liter) | Fuel Cost (Rp) |
|---|---|---|---|---|---|
| 20/11/2024 | Yamaha NMAX/2DP R AT 155 CC 2016 (18 Blood bags) | I | 11,1 km | Rp10.000 | Rp 3.171 |
| | | | 2,6 km | Rp10.000 | Rp 743 |
| | | | 7,80 km | Rp10.000 | Rp 2.229 |
| | | | 9 km | Rp10.000 | Rp 2.571 |
| | | | 2,6 km | Rp10.000 | Rp 743 |
| | | | 15 km | Rp10.000 | Rp 4.286 |
| | | II | 7,9 km | Rp10.000 | Rp 2.257 |
| | | | 9 km | Rp10.000 | Rp 2.571 |
| | | | 2,6 km | Rp10.000 | Rp 743 |
| | | | 23,4 km | Rp10.000 | Rp 6.686 |
| | | | 16,7 km | Rp10.000 | Rp 4.771 |
| | | III | 18,7 km | Rp10.000 | Rp 5.343 |
| | | | 17,4 km | Rp10.000 | Rp 4.971 |
| **Total** | | | 143,8 km | | Rp 41.085 |
| 21/11/2024 | Yamaha NMAX/2DP R AT 155 CC 2016 (18 Blood bags) | I | 14,7 km | Rp10.000 | Rp 4.200 |
| | | | 14,2 km | Rp10.000 | Rp 4.057 |
| | | | 53,8 km | Rp10.000 | Rp 15.371 |
| | | | 62,4 km | Rp10.000 | Rp 17.829 |
| | | II | 19,4 km | Rp10.000 | Rp 5.543 |
| | | | 17,9 km | Rp10.000 | Rp 5.114 |
| | | | 18 km | Rp10.000 | Rp 5.143 |
| | | | 27 km | Rp10.000 | Rp 7.714 |
| | | | 15,2 km | Rp10.000 | Rp 4.343 |
| | | | 30 km | Rp10.000 | Rp 8.571 |
| | | III | 2,6 km | Rp10.000 | Rp 743 |
| | | | 18,8 km | Rp10.000 | Rp 5.371 |
| | | | 6,8 km | Rp10.000 | Rp 1.943 |
| | | | 2,6 km | Rp10.000 | Rp 743 |
| **Total** | | | 303,4 km | | Rp 86.712 |

Source: PMI Jember's Secondary Data, 2024

On November 20, 2024, the distribution process was executed with two motors operating in each shift, thereby covering a total distance of 143.8 kilometers. Considering a fuel consumption of 35 kilometers per liter and the fuel type utilized, Pertalite, with a cost of Rp10,000 per liter, the total expenditure amounted to Rp41,085. In a subsequent day, on 21st of November 2024, the same transportation and fuel were utilized, resulting in costs of Rp86,712 for a total of 303,4 kilometers.

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## 4. Result and Discussion

The application of the Clarke-Wright Savings algorithm has formulated routes that emphasize efficiency, as illustrated in the following table. This approach utilizes savings values to construct routes, leading to a substantial reduction in both the total distance traveled and the number of trips.

**Table 5. Distribution Route Proposed by Clarke-Wright Savings Algorithm**

| Date | Shift | Formed Route by *Clarke-Wright Savings Algorithm* | Total Distance (km) | Total Demand (Blood bags) | Total Supply (Blood samples) | Transportation |
|---|---|---|---|---|---|---|
| 20/11/2024 | I | 0 – 11 – 4 – 2 – 1 – 0 | 8,7 km | 11 | 2 | Motor |
| | | 0 – 10 – 4 – 11 – 1 – 0 | 11,7 km | 7 | 9 | Motor |
| | II | 0 – 6 – 5 – 4 – 11 – 2 – 1 – 0 | 19,7 km | 16 | 15 | Motor |
| | III | 0 – 9 – 5 – 2 – 11 – 1 – 0 | 18,7 km | 14 | 5 | Motor |
| 21/11/2024 | I | 0 – 13 – 8 – 6 – 4 – 2 – 0 | 73,2 km | 9 | - | Motor |
| | II | 0 – 10 – 5 – 9 – 6 – 4 – 0 | 24,2 km | 20 | 2 | Car |
| | | 0 – 12 – 7 – 11 – 1 – 0 | 23,7 km | 14 | 7 | Motor |
| | | 0 – 11 – 3 – 0 | 34,9 km | 6 | - | Motor |
| | III | 0 – 7 – 5 – 10 – 9 – 12 – 4 – 11 – 1 – 0 | 30,1 km | 18 | - | Motor |

Source: Data Processing Results, 2024

The following table details the calculation of distribution costs after route optimization. Variations in costs are driven by the reduction in mileage and the additional use of car vehicles to accommodate new routes with total demand that exceeds the capacity of motorcycles.

**Table 6. Total Fuel Cost with Clarke-Wright Savings Algorithm**

| Date | Shift | Route | Total Distance (km) | Transportation | Fuel Consumption (km/l) | Fuel Cost (Rp) |
|---|---|---|---|---|---|---|
| 20/11/2024 | I | 1 | 8,7 km | Motor | 35 km/l | Rp 2.486 |
| | | 2 | 11,7 km | Motor | 35 km/l | Rp 3.343 |
| | II | 1 | 19,7 km | Motor | 35 km/l | Rp 5.629 |
| | III | 1 | 18,7 km | Motor | 35 km/l | Rp 5.343 |
| **Total Distance** | | | 58,8 km | **Total Cost** | | Rp 16.801 |
| 21/11/2024 | I | 1 | 73,2 km | Motor | 35 km/l | Rp 20.914 |
| | II | 1 | 24,2 km | Car | 12,5 km/l | Rp 19.360 |
| | | 2 | 23,7 km | Motor | 35 km/l | Rp 6.771 |
| | | 3 | 34,9 km | Motor | 35 km/l | Rp 9.971 |
| | III | 1 | 30,1 km | Motor | 35 km/l | Rp 8.600 |
| **Total Distance** | | | 186,1 km | **Total Cost** | | Rp 65.913 |

Source: Data Processing Results, 2024

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As the Clarke-Wright Savings algorithm prioritizes savings, it tends to generate less sequential route orders. Consequently, the Nearest Neighbor method is employed in conjunction with the former to ensure optimal efficiency. The following table illustrates the routes that have been formulated based on the closest distance between locations.

**Table 7. Distribution Route Proposed by Nearest Neighbor**

| Date | Shift | Formed Route by Nearest Neighbor | Total Distance (km) | Total Demand (Blood bags) | Total Supply (Blood samples) | Transportation |
|---|---|---|---|---|---|---|
| 20/11/2024 | I | 0 – 1 – 2 – 11 – 4 – 0 | 8,7 km | 11 | 2 | Motor |
| | | 0 – 1 – 11 – 4 – 10 – 0 | 13,8 km | 7 | 9 | Motor |
| | II | 0 – 1 – 2 – 11 – 4 – 6 – 5 – 0 | 20,3 km | 16 | 15 | Motor |
| | III | 0 – 9 – 5 – 2 – 11 – 1 – 0 | 20,6 km | 14 | 5 | Motor |
| 21/11/2024 | I | 0 – 2 – 4 – 6 – 8 – 13 – 0 | 71,7 km | 9 | - | Motor |
| | II | 0 – 4 – 10 – 6 – 5 – 9 – 0 | 23,8 km | 20 | 2 | Car |
| | | 0 – 1 – 11 – 7 – 12 – 0 | 23,7 km | 14 | 7 | Motor |
| | | 0 – 11 – 3 – 0 | 34,9 km | 6 | - | Motor |
| | III | 0 – 1 – 11 – 4 – 10 – 7 – 9 – 5 – 12 – 0 | 28,5 km | 18 | - | Motor |

Source: Data Processing Results, 2024

The Nearest Neighbor method, which focuses on sequentially selecting the closest locations, produces a different route than the Clarke-Wright Savings algorithm. The following table details the distribution costs calculated based on the Nearest Neighbor route

**Table 8. Total Fuel Cost with Nearest Neighbor**

| Date | Shift | Route | Total Distance (km) | Transportation | Fuel Consumption (km/l) | Fuel Cost (Rp) |
|---|---|---|---|---|---|---|
| 20/11/2024 | I | 1 | 8,7 km | Motor | 35 km/l | Rp 2.486 |
| | | 2 | 13,8 km | Motor | 35 km/l | Rp 3.943 |
| | II | 1 | 20,3 km | Motor | 35 km/l | Rp 5.800 |
| | III | 1 | 20,6 km | Motor | 35 km/l | Rp 5.886 |
| **Total Distance** | | | **64,8 km** | **Total Cost** | | **Rp 18.115** |
| 21/11/2024 | I | 1 | 71,7 km | Motor | 35 km/l | Rp 20.486 |
| | II | 1 | 23,8 km | Car | 12,5 km/l | Rp 19.040 |
| | | 2 | 23,7 km | Motor | 35 km/l | Rp 6.771 |
| | | 3 | 34,9 km | Motor | 35 km/l | Rp 9.971 |
| | III | 1 | 28,5 km | Motor | 35 km/l | Rp 8.143 |
| **Total Distance** | | | **182,6 km** | **Total Cost** | | **Rp 64.411** |

Source: Data Processing Results, 2024

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The objective of this study is to evaluate the distance and cost efficiency. To provide a comprehensive analysis, table 9 presents a cost comparison between the Nearest Neigbor method and the Clarke-Wright Savings algorithm, focusing on the impact on the total distribution cost.

**Table 9. Total Distance and Cost Comparison**

| Date | Shift | Total Hospitals | Initial Route Distance (km) | CWS Route Distance (km) | NN Route Distance (km) | Initial Cost | CWS Cost | NN Cost | Best Method | Savings |
|---|---|---|---|---|---|---|---|---|---|---|
| 20/11/2024 | I | 7 Hospital points | 48,1 | 20,4 | 22,5 | Rp13.743 | Rp5.829 | Rp6.429 | CWS | CWS (58%) NN (53%) |
| | II | | 56,9 | 19,7 | 20,3 | Rp17.028 | Rp5.629 | Rp5.800 | CWS | CWS (67%) NN (66%) |
| | III | | 36,1 | 18,7 | 20,6 | Rp10.314 | Rp5.343 | Rp5.886 | CWS | CWS (48%) NN (43%) |
| 21/11/2024 | I | 13 Hospital Points | 145,1 | 73,2 | 71,1 | Rp41.457 | Rp20.914 | Rp20.486 | NN | CWS (50%) NN (51%) |
| | II | | 127,5 | 82,8 | 82,4 | Rp36.428 | Rp.36.102 | Rp35.782 | NN | CWS (1%) NN (2%) |
| | III | | 30,8 | 30,1 | 28,5 | Rp8.800 | Rp8.600 | Rp8.143 | NN | CWS (2%) NN (7%) |

Source: Data Processing Results, 2024

Based on the analysis results in the table above, it can be concluded that the greater the number of hospital locations that must be visited in a single shift, the higher the total travel distance tends to be. This also affects fuel consumption costs, which increase for both the Clarke-Wright Savings Algorithm and the Nearest Neighbor method.

The findings of this study align with Grondys (2020), which demonstrated that the Clarke-Wright Savings Algorithm achieved an 18.75% reduction in inter-warehouse distribution costs. Study of Grondys (2020) involved a larger number of locations and a higher level of complexity, resulting in lower savings compared to this study, which focused on fewer locations with simpler operational conditions. Thus, this study highlights the effectiveness of the Clarke-Wright Savings Algorithm in simpler operational settings, such as local-scale blood distribution. These findings complement previous research that primarily focused on large-scale applications with higher complexity, providing new insights and a more comprehensive understanding of the algorithm's implementation.

Meanwhile, this study also compares the Nearest Neighbor method with the Clarke-Wright Savings Algorithm, as conducted by Kusuma et al. (2021), who found that over six days of

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research, the Nearest Neighbor method produced more optimal routes on five days compared to the Clarke-Wright Savings Algorithm. However, the results of this study do not fully align with Kusuma et al. (2021), as Nearest Neighbor did not always outperform the Clarke-Wright Savings Algorithm in the context of blood distribution at PMI Jember. In some cases, the Nearest Neighbor method provided additional savings, but under certain conditions, it resulted in longer travel distances and higher distribution costs compared to the Clarke-Wright Savings Algorithm. This suggests that the effectiveness of each method is highly dependent on the configuration of distribution points and the travel patterns that emerge.

## 5. Conclusion

In accordance with the results of the analysis and discussion that have been presented, the following conclusions can be drawn:

1. The Clarke-Wright Savings algorithm demonstrated a higher efficacy than the Nearest Neighbor method on the 20th of November 2024, with cost savings ranging from 48% to 67% in each shift, when servicing seven hospital locations. Conversely, the Nearest Neighbor method exhibited superior efficiency on the 21st of November 2024 when the number of destination locations increased to 13 hospitals.
2. The efficiency comparison indicates that the number of distribution destination locations has a significant impact on the performance of both methods. On the 20th of November 2024, Clarke-Wright Savings algorithm demonstrates superior performance with seven locations, while Nearest Neighbor shows higher efficiency on the 21st with 13 locations.

## 6. Recommendations for Enhancing the Efficiency of Blood Distribution in PMI

Based on the findings of this study, several recommendations are proposed to enhance the efficiency and effectiveness of blood distribution at both the local and national levels.

1. UDD PMI Jember Regency is advised to provide training to drivers regarding logbook filling compliance and conduct periodic audits, considering that during the research it was found that drivers were not orderly in filling out logbooks, which could potentially reduce the accuracy of distribution data.
2. PMI Jember should digitize its distribution logbook to ensure more organized record-keeping and easier access for evaluation. Additionally, PMI as a whole can implement an application-based recording system that enables all branches to report data more quickly and accurately.
3. PMI at the national level can develop a technology-based system, such as GIS-based route planning, to enhance the efficiency of blood distribution across various regions.

## 7. Limitations and Future Research Directions

This study is subject to several limitations that must be considered when interpreting the results. These limitations also present opportunities for future research to enhance the scope and applicability of blood distribution optimization.

1. The analysis is based on two days of distribution data, which may not fully capture long-term distribution patterns. Future research could expand the dataset to include a more extended period, allowing for a more robust evaluation of seasonal variations and operational trends.

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2. The current study does not consider real-time traffic conditions, such as congestion patterns and changes in vehicle speed, which can significantly impact distribution efficiency. Future studies could integrate dynamic traffic data to improve route optimization under varying conditions.
3. The model assumes static blood demand and does not account for fluctuations in demand over time. Future research should incorporate stochastic demand modelling and real-time forecasting techniques to enhance responsiveness in supply chain planning.
4. The proposed method primarily focuses on general route efficiency and may not be fully adaptable to emergency situations that require immediate and flexible distribution strategies. Further studies should explore hybrid models that balance efficiency with rapid response capabilities, especially for critical and high-priority cases.

By addressing these limitations, future research can contribute to a more comprehensive and practical approach to optimizing blood distribution, ensuring both efficiency and adaptability in real-world applications.

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