

## Optimizing Distribution Route of Packed Drinking Water with The Clarke and Wright Savings and Nearest Neighbor Methods (Case Study of PT. GSI)

Rian Puji Kusuma<sup>1</sup>, Dwi Agustina Kurniawati<sup>2\*</sup>, Dwi Kristanto<sup>3</sup>,  
Noordin Mohd. Yusof<sup>4</sup>, Kuan Yew Wong<sup>5</sup>

<sup>1,2,3</sup>Optimization, Operation Research and Industrial System Research Group (2ORIS-RG)  
Industrial Engineering Department, Faculty of Science and Technology,  
Universitas Islam Negeri Sunan Kalijaga Yogyakarta

<sup>4,5</sup>School of Mechanical Engineering, Faculty of Engineering,  
Universiti Teknologi Malaysia  
Johor, Malaysia

Email: \*[dwi.kurniawati@uin-suka.ac.id](mailto:dwi.kurniawati@uin-suka.ac.id)

### Abstract

*In the business, distribution has a very important role. The distribution process must be able to deliver products on time while it also reduces the transportation costs which can consume around 50% of the company's total logistics costs. If distribution costs can be reduced, it can indirectly increase the company's profit. PT. GSI, located in Yogyakarta, is a distributor of packed drinking water company with brand "PLG". In determining the distribution route, PT. GSI does not use any scientific method and only uses the driver's intuition. The purpose of this study is to optimize the distribution route of the "PLG" packed drinking water delivery to obtain the minimum mileage by using the Clarke and Wright Savings and Nearest Neighbor methods. The Clarke and Wright Savings method and the Nearest Neighbor method are used because the customer locations are far from each other and there are also customers whose delivery locations are centered on one delivery area, so that the calculation of distance savings is needed. Then the evaluation is done to determine which method is better. The comparison of the solution for data on 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>, 4<sup>th</sup>, and 6<sup>th</sup> March 2021 showed that the Nearest Neighbor method proposed best solution while data on 5<sup>th</sup> March 2021 showed that Clarke and Wright Savings giving the best solution. The results show that the Nearest Neighbor method provides better result in determining the distribution routes of PT. GSI.*

**Keywords : Distribution Route, Nearest Neighbor, Clarke and Wright Savings, Mileage, Saving Matrix.**

### INTRODUCTION

Companies that want to win the business must improve the customer satisfaction. One thing that can improve the customer satisfaction is though providing on time delivery in the distribution. In product distribution, the product delivery can have several destinations or customers then result in several routes. If the distribution routes are not well managed, this can cause higher distance and longer time for distribution then result for higher distribution costs and waste the energy and time (Muhammad et al., 2017).

By optimizing the distribution route, the total travel distance and travel time can be minimized (Pujawan, I Nyoman, 2010). The optimal method is a method that produces the shortest total mileage, short distribution time,

and minimal fuel costs (Agustina & Fauzi, 2016). In the Nearest Neighbor method, the route problem is solved by determining the closest point with the shortest distance (Abadi et al., 2014). Clarke And Wright Savings or Savings Heuristics method aims to minimize mileage, time, or costs by looking at all existing constraints (Kurniawan et al., 2014).

## LITERATURE REVIEW

There are several previous studies related to this research. Determined the distribution routes using the Clarke and Wright Savings method and Sequential Insertion with the aim of minimizing the distance and time based on the consideration of limited working hours (Octora et al., 2014). Determined the distribution routes using the Clarke and Wright Savings method with the aim of minimizing distance and costs based on vehicle capacity considerations (Kusuma & Sumiati., 2020). Determined the distribution route using the Clarke and Wright Savings and Nearest Neighbor methods with the aim of minimizing the distance and time based on considerations of distance, time, and cost (Enggraini et al., 2020). Determined the distribution routes using the Clarke and Wright Savings and Nearest Neighbor methods with the aim of minimizing costs based on consideration of the distance between distant destinations (Pamungkas et al., 2013).

Distribution is the movement of goods from the place of production to the several destinations or consumers (Pujawan, I Nyoman, 2010). The problem occurs in distribution process can be caused by internal factor in the company or external factor of the company. External constraints come from the way the distribution is carried out for delivering the products to the destination. Meanwhile, the internal constraints are the company's policies regarding the distribution Tjiptono, 2008).

Distributors are third parties that responsible in distributing the products from factories or warehouses without changing anything the products. Distributors must be able to deliver the products according with the customer requested such as the type, the size, the quantity, and the quality of the products. Some challenging issue in the distribution is to determine the shortest and appropriate route. Determining the route in the distribution is important. The route distribution problem can be optimized by using Capacitated Vehicle Routing Problem (CVRP). The CVRP can be solved using algorithms such as Clarke and Wright, Sweep algorithm, and Fisher and Jaikumar algorithm (Morohito et al., 2018).

The Vehicle Routing Problem (VRP) is determination of optimal routes from the depot to the several customers by taking into account a number of limitations (Laporte, 1992). Clarke and Wright Savings is an algorithm used to solve vehicle route problems by swapping a set of routes at each step to get a better set of routes (Octora et al., 2014). Nearest Neighbor is one of the algorithms categorized in the heuristic method. The purpose of this method is to find the best route. This method is said to be effective because it distributes products based on the closest distance from the last location of the vehicle (Pujawan, I Nyoman, 2010),

The VRP is one of the most well-known problems in Operational Research. The goal is to determine the distribution route in which there are several obstacles in the distribution and provide a minimum total distribution cost. Many studies and research are performed in the VRP area, since its vital role in planning the distribution and logistics systems of various sectors (Yeun et al., 2008). The VRP consists of several customers, each of which has a known number of requested product and must be supplied from a single depot. The delivery routes are starting and finishing at the depot, so that all customers' demands can be met. In CVRP, each vehicle has a maximum load capacity in an effort to deliver goods (Baker & Ayechew, 2003).

The VRP has several classifications. This arises due to various factors, objective functions and also constraints under certain conditions. Some classifications of VRP are as follows (Priyandari, 2008).

1. VRP Time Windows (VRPTW), where each customer in the service is determined by a time limit and must be done within the time windows of each customer.
2. Capacitated VRP (CVRP), in which the distribution vehicle has a limited capacity.
3. VRP Split Delivery (VRPSD), where customers or consumers can be served by more than one vehicle. Limited capacity in vehicles is the reason why customers can be served by more than one vehicle.
4. VRP Multiple Depots (VRPMD), which has more than one depot.
5. VRP Pick Up and Delivery (VRPPD), in which the vehicle performs two tasks at once, including product pick-up and delivery.
6. VRP Multiple Trips (VRPMT), in order to meet the consumer demands, one vehicle can takes several routes (multi trips).
7. VRP Multiple Products (VRPMP), which is where the customers' demands are more than one product.

8. Periodic VRP, where service to consumers can be carried out at some time during the planning horizon where the planning horizon is only valid on one day.
9. VRP Heterogeneous Fleet of Vehicles (VRPHFV), in which the characteristics and types of vehicles used by the companies are vary.
10. Dynamic VRP (DVRP), which is if there is a new customer in creating a route, the new customer is inserted into an additional route when creating the main delivery route.
11. Stochastic VRP (SVRP), in which the number of customers, service time, and the customer requests are uncertain. Every customer has the possibility of not being visited every day.

CVRP is one of the most common optimization problems in transportation, distribution, and logistics. The purpose of the CVRP is to determine the total travel time while at each route, it is not allowed to exceed the vehicle capacity. In this case, the aim is to obtain the best method for determining the shortest distribution route [12].

The Clarke and Wright Savings algorithm is the heuristic algorithm that is most often used in the VRP. There are several steps in the Clarke and Wright Savings method (Clarke & Wriht, 1964).

1. Determine the allocation of vehicles and the maximum number of vehicle capacities.
2. Form a distance matrix.
3. Calculate the value of savings.

$$S_{ij} = C_{0i} + C_{0j} - C_{ij}$$

$C_{0i}$  = distance from depot to node  $i$

$C_{ij}$  = distance from node  $i$  to node  $j$

$S_{ij}$  = value of distance savings from node  $i$  to node  $j$

4. Create a savings matrix.
5. Selects a cell in which two routes can be combined into a single route.

Nearest Neighbor is one of the algorithms included also in the heuristic method. The purpose of this method is to find the best route by distributing products based on the closest distance to the last vehicle location (Pujawan, I Nyoman, 2010). There are several steps in the solution using the Nearest Neighbor method.

1. Set the origin point of departure.
2. Find the shortest distance from the origin to another point (destination point) and connect the two.
3. The currently selected destination point will be the point of origin for the next departure.
4. Checking whether all points have been visited or not.
  - a. If there is a point that has not been visited, repeat step 1.
  - b. If all points have been visited, go to step 5.
5. Route is formed.
6. Finished.

## **RESEARCH METHODS**

The object of this research is the distribution route of PT. GSI, starting from PT.GSI's warehouse to the several agents (consumers) who ordered "PLG" Packaged Drinking Water. The study is limited to the distribution areas in West Sleman, North Sleman, North Bantul, and West Yogyakarta. The data required in this study is primary and secondary data. The primary data required are vehicle distribution system, the type of vehicle, vehicle capacity, distance between warehouses to the consumers and distances between consumers. The secondary data used in this study are consumer's demand data, the delivery date and the agent's address data. This study uses interview and observation for data collection.

There are several steps used to determine the distribution routes using the Clarke and Wright Savings and Nearest Neighbor methods. The first step is identifying the problem, conducting a literature study, and collecting the data. Then data processing is carried out using the Clarke and Wrights savings method which begins with identifying the distance matrix, determining the savings matrix, allocating consumers to the routes, and then sorting the distribution routes. After that, validation is carried out using the Nearest Neighbor method which begins with grouping based on the previous method, namely the Clarke and Wright Savings method and then

determining the distribution route. After getting the results of data processing then the two methods are compared. The best method is method that has the least total travel distance. Figure 1 shows the research method implemented in this research.

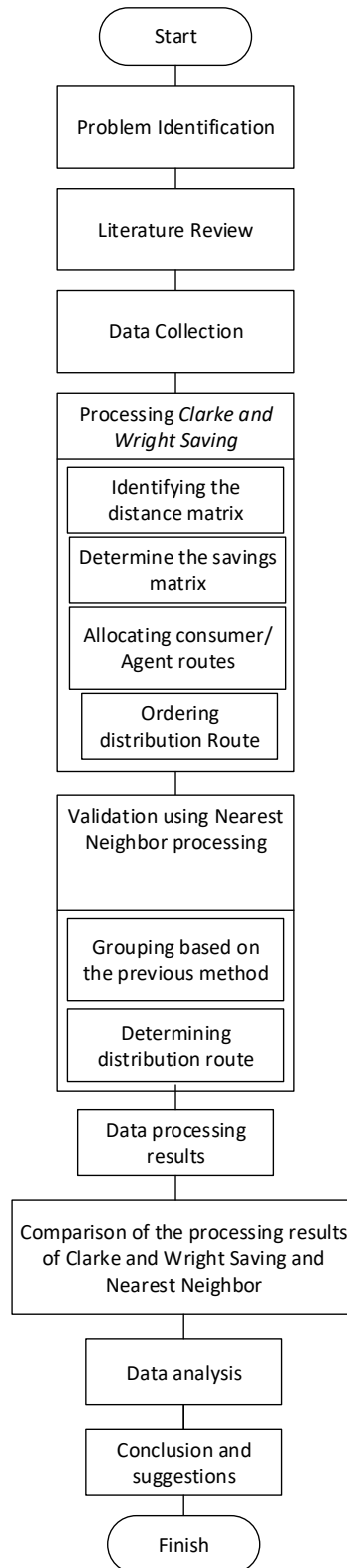


Figure 1. Research Method Flowchart

## COLLECTING DATA

Data for the agents (customers) of PT. GSI on 1<sup>st</sup> March 2021 is shown in Table 1 while the data for the agents on 1<sup>st</sup> – 6<sup>th</sup> March 2021 are shown in the appendix. Table 2 shows the actual distribution route on 1<sup>st</sup> - 6<sup>th</sup> March 2021.

**Table 1. Customers' Data on 1<sup>st</sup> March 2021**

No	Date	Code	Customer's name	Address
1	2021-03-01	A1	ANITA DND	Jl. Angrek Tegalorejo, Geblagan, Tamantirto, Kec. Kasihan, Bantul, Daerah Istimewa Yogyakarta
2	2021-03-01	A2	INDRO. TK	Jl. Bibis No.11, Area Sawah, Sidokarto, Kec. Godean, Kabupaten Sleman, Daerah Istimewa Yogyakarta
3	2021-03-01	A3	MARDI. BP (GAMPING)	Jl. Rajawali, Ngebel, Tamantirto, Kec. Kasihan, Bantul, Daerah Istimewa Yogyakarta
4	2021-03-01	A4	NARAYA SWALAYAN	Jalan Jogja Ring Road Selatan No.68, Kasihan, Brajan, Tamantirto, Bantul, Daerah Istimewa Yogyakarta
5	2021-03-01	A5	BAZAR SWALAYAN	Jl. Garuda No.170E, Gejayan, Condongcatur, Kec. Depok, Kabupaten Sleman, Daerah Istimewa Yogyakarta
6	2021-03-01	A6	KOPMA UNY	Gedung Business Centre KOPMA UNY, Jl. Colombo, Caturtunggal, Sleman, Karang Malang, Caturtunggal, Kec. Depok, Kabupaten Sleman, Daerah Istimewa Yogyakarta
7	2021-03-01	A7	PAK EKO / SRI REJEKI	Jl. Sriti 20, Demangan Baru, Caturtunggal, Kec. Depok, Kabupaten Sleman, Daerah Istimewa Yogyakarta
8	2021-03-01	A8	PERKASA MART	Jl. Cendrawasih No.90b, Ngringin, Condongcatur, Kec. Depok, Kabupaten Sleman, Daerah Istimewa Yogyakarta
9	2021-03-01	A9	POPEYE GUDANG	Jl. Komojoyo No.27-22, Karang Gayam, Caturtunggal, Kec. Depok, Kabupaten Sleman, Daerah Istimewa Yogyakarta
10	2021-03-01	A10	SYIFA. TOKO	Jl. Serdadu, Serut, Madurejo, Kec. Prambanan, Kabupaten Sleman, Daerah Istimewa Yogyakarta

**Table 2. Actual distribution route on 1<sup>st</sup> - 6<sup>th</sup> March 2021**

Date	Actual Route	Total Distance
1-3-2021	G-A6-A1-A2-A3-A4-A5-A7-A8-A9-A10-G	91,4 km
2-3-2021	G-A3-A1-A2-A4-A5-A6-A7-A8-A9-A10-A11-A12-A13-A14-A15-A16-A17-A18-G	191 km
3-3-2021	G-A10-A1-A2-A3-A4-A5-A6-A7-A8-A9-A11-A12-A13-A14-G	166,55 km
4-3-2021	G-A7-A1-A2-A3-A4-A5-A6-A8-G	70 km
5-3-2021	G-A2-A1-A3-A4-A5-A6-A7-A8-A9-G	109,3 km
6-3-2021	G-A9-A2-A1-A3-A4-A5-A6-A7-A8-A10-A11-A12-G	187,6 km

## RESULTS AND DISCUSSION

### 1. Distribution Route Analysis

The existing distribution route of PT. GSI is still not optimal as shown in Table 2. The current distribution route in the areas of West Sleman, North Sleman, North Bantul, and West Yogyakarta is determined only based

on the driver's intuition. The product delivery at PT. GSI is carried out every day and the product are delivered next day after the consumer places an order. The following Table 3 is the distribution route as the solution proposed by the Clarke and Wright Savings method.

**Table 3. Distribution Route Proposed by Clarke and Wright Savings Method**

Date	Formed route
	<i>Clarke and Wright Savings</i>
1 <sup>st</sup> March 2021	G-A4-A10-A8-A7-A6-A9-A5-A2-A1-A3-G <b>Total distance 82,3 km</b>
2 <sup>nd</sup> March 2021	G-A1-A4-A3-A9-A18-A6-A11-A7-A17-A13-A12-A10-A8-A16-A14-A15-A5-A2-G <b>Total distance 105,14 km</b>
3 <sup>rd</sup> March 2021	G-A5-A2-A12-A13-A8-A14-A9-A7-A10-A6-A3-A1-A4-A11-G <b>Total distance 133,2 km</b>
4 <sup>th</sup> March 2021	G-A1-A2-A4-A5-A7-A6-A8-A3-G <b>Total distance 56,3 km</b>
5 <sup>th</sup> March 2021	G-A4-A5-A1-A2-A3-A6-A7-A8-A9-G <b>Total distance 85,6 km</b>
6 <sup>th</sup> March 2021	G-A10-A1-A12-A11-A6-A8-A3-A2-A4-A9-A5-A7-G <b>Total distance 115,916 km</b>

Meanwhile, in the Nearest Neighbor method, the data processing is done by sorting the route based on the minimum distance. The method results in six routes carried out for six days. The following Table 4 is a route distribution as the solution proposed by the Nearest Neighbor method.

**Table 4. Distribution Route Proposed by Nearest Neighbor Method**

Date	Formed route
	<i>Nearest Neighbor</i>
1 <sup>st</sup> March 2021	G-A4-A3-A1-A2-A6-A9-A7-A5-A8-A10-G <b>Total distance 63,2 km</b>
2 <sup>nd</sup> March 2021	G-A14-A16-A15-A8-A3-A4-A17-A7-A9-A13-A12-A10-A18-A6-A11-A1-A5-A2-A1-G <b>Total distance 91,34 km</b>
3 <sup>rd</sup> March 2021	G-A6-A11-A10-A7-A14-A8-A13-A9-A3-A4-A2-A12-A5-A1-G <b>Total distance 119,075 km</b>
4 <sup>th</sup> March 2021	G-A1-A3-A7-A6-A8-A5-A4-A2-G <b>Total distance 53 km</b>
5 <sup>th</sup> March 2021	G-A9-A7-A8-A4-A6-A2-A1-A5-A3-G <b>Total distance 87 km</b>
6 <sup>th</sup> March 2021	G-A7-A9-A10-A2-A4-A1-A12-A11-A6-A8-A3-A5-G <b>Total distance 105,016 km</b>

## 2. Proposed Distribution Route

In this research, the solutions proposed for the distribution route of the “PLG” packaged drinking water distribution indicate that the Nearest Neighbor method can reduce more the total travel distance compared with the existing route and the Clarke and Wright Savings method, as shown in Table 5.

Based on the Table 5, it can be concluded that the Nearest Neighbor method produces a delivery route that is shorter than the initial route (driver's intuition) and the Clarke and Wright Savings method. The Nearest Neighbor method can be used as a better method for determining the distribution route of PT. GSI for “PLG” packaged drinking water distribution in the areas of West Sleman, North Sleman, North Bantul, and West Yogyakarta.

**Table 5. Total Distance Comparison**

Date	Formed route			Total Request (Liter)	Best Method	Total Savings from Selected Routes	Percentage
	Driver's intuition	Clarke and Wright Savings	Nearest Neighbor				
March 1, 2021	G-A6-A1-A2-A3-A4-A5-A7-A8-A9-A10-G <b>Total distance 91,4 km</b>	G-A4-A10-A8-A7-A6-A9-A5-A2-A1-A3-G <b>Total distance 82,3 km</b>	G-A4-A3-A1-A2-A6-A9-A7-A5-A8-A10-G <b>Total distance 63,2 km</b>	5.240,28 (Still can be accommodated by the tailgate)	Nearest Neighbor	28,2 km	Clarke and Wright Savings: 10 % Nearest Neighbor: 31%
March 2, 2021	G-A3-A1-A2-A4-A5-A6-A7-A8-A9-A10-A11-A12-A13-A14-A15-A16-A17-A18-G <b>Total distance 191 km</b>	G-A1-A4-A3-A9-A18-A6-A11-A7-A17-A13-A12-A10-A8-A16-A14-A15-A5-A2-G <b>Total distance 105,14 km</b>	G-A14-A16-A15-A8-A3-A4-A17-A7-A9-A13-A12-A10-A18-A6-A11-A1-A5-A2-A1-G <b>Total distance 91,34 km</b>	3.176,27 (Still can be accommodated by the tailgate)	Nearest Neighbor	99,66 km	Clarke and Wright Savings: 45% Nearest Neighbor: 52%
March 3, 2021	G-A10-A1-A2-A3-A4-A5-A6-A7-A8-A9-A11-A12-A13-A14-G <b>Total distance 166,55 km</b>	G-A5-A2-A12-A13-A8-A14-A9-A7-A10-A6-A3-A1-A4-A11-G <b>Total distance 133,2 km</b>	G-A6-A11-A10-A7-A14-A8-A13-A9-A3-A4-A2-A12-A5-A1-G <b>Total distance 119,075 km</b>	2.127,26 (Still can be accommodated by the tailgate)	Nearest Neighbor	47,475 km	Clarke and Wright Savings: 20% Nearest Neighbor: 29%
March 4, 2021	G-A7-A1-A2-A3-A4-A5-A6-A8-G <b>Total distance 70 km</b>	G-A1-A2-A4-A5-A7-A6-A8-A3-G <b>Total distance 56,3 km</b>	G-A1-A3-A7-A6-A8-A5-A4-A2-G <b>Total distance 53 km</b>	5.081,95 (Still can be accommodated by the tailgate)	Nearest Neighbor	17 km	Clarke and Wright Savings: 20% Nearest Neighbor: 24%
March 5, 2021	G-A2-A1-A3-A4-A5-A6-A7-A8-A9-G <b>Total distance 109,3 km</b>	G-A4-A5-A1-A2-A3-A6-A7-A8-A9-G <b>Total distance 85,6 km</b>	G-A9-A7-A8-A4-A6-A2-A1-A5-A3-G <b>Total distance 87 km</b>	6.886,10 (Still can be accommodated by the tailgate)	Clarke and Wright Savings	23,7 km	Clarke and Wright Savings: 22% Nearest Neighbor: 20%
March 6, 2021	G-A9-A2-A1-A3-A4-A5-A6-A7-A8-A10-A11-A12 <b>Total distance 187,6 km</b>	G-A10-A1-A12-A11-A6-A8-A3-A2-A4-A9-A5-A7-G <b>Total distance 115,916 km</b>	G-A7-A9-A10-A2-A4-A1-A12-A11-A6-A8-A3-A5-G <b>Total distance 105,016 km</b>	5.029,33 (Still can be accommodated by the tailgate)	Nearest Neighbor	82,584 km	Clarke and Wright Savings: 38% Nearest Neighbor: 44%

**CONCLUSION AND FUTURE RESEARCH**

1. On March 1, 2021, the selected route is the route that uses the Nearest Neighbor method with a total distance of 63.2 km, so that a total distance savings of 28.2 km is obtained. On March 2, 2021, the route chosen was the route using the Nearest Neighbor method with a total distance of 91.34 km, so that a total distance savings of 99.66 km was obtained. On March 3, 2021, the selected route is the route that uses the Nearest Neighbor method with a total distance of 119.075 km, so that a total distance savings of 47.475 km is obtained. On March 4, 2021, the selected route is the route that uses the Nearest Neighbor method with a total distance of 53 km, so that a total distance savings of 17 km is obtained. On March 5, 2021, the selected route is the route that uses the Clarke and Wright Savings method with a total distance of 85.6 km, so that a total distance savings of 23.7 km is obtained. On March 6, 2021, the selected route is the route that uses the Nearest Neighbor method with a total distance of 105.016 km, so that a total distance savings of 82.584 km is obtained.

2. Based on the results of the study, 5 out of 6 days have a minimum total travel distance when using the Nearest Neighbor method. So, it can be concluded that the Nearest Neighbor method is better than the Clarke and Wright Savings method to be used as an evaluation on March 1 to March 6, 2021.
3. For future research, the future study can consider the customer's time window for delivery and also it is necessity to develop a software or application as a decision-making tool for determining the best distribution route.

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