World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

Optimizing the drinking water gallon distribution using vehicle routing problems with pick-up and delivery approach (Case Study of Berkah RO Drinking Water Depot)

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World Journal of Advanced Research and Reviews, 2023, 18(02), 979–1002

Publication history: Received on 02 April 2023; revised on 13 May 2023; accepted on 16 May 2023

Article DOI: https://doi.org/10.30574/wjarr.2023.18.2.0881

Abstract

Distribution activities play an essential role in the industry nowadays. Every company will design new effective and efficient strategies to improve its distribution systems, such as route selection, scheduling the number of vehicles, and many others. The optimal route selection model is an adequately considered issue in product distribution. The problem model commonly arises in the distribution activity is the vehicle routing problem (VRP). This distribution problem model also occurred in one of the drinking water gallon companies, Berkah RO Drinking Water Depot, where they still subjectively selected the route. In addition, the factor of damaged vehicles causes some demands for water gallons not to be fulfilled. The problem in this company is categorized as a vehicle routing problem (VRP) model with pick-up and delivery. This research uses a saving matrix and nearest-neighbor methods to solve the problem of determining the optimal vehicle route. An application is then developed based on the algorithm for determining the optimal vehicle route with a saving matrix and nearest-neighbor methods. This application aims to acquire faster results than manual calculations if each customer's demand changes. The final result of this research is determining the optimal vehicle routing with the shortest distance considering the arrival and departure time allocation and total distribution cost.

Keywords: Distribution; VRP Pick-up and Delivery; Saving Matrix; Nearest-Neighbor; Application

1. Introduction

In today's industrial world, distribution activities are essential to a company's sustainability. Distribution is a marketing activity for more accessible delivery activities for products and services from producer to consumer [1]. The company that does the distribution activities or goods deliveries must be able to determine the proper distribution route planning by considering the company's needs and following its characteristics and distribution strategy. Arvianto et al. (2014) mentioned that several vital considerations in distribution activity planning are route selection, the fleet of vehicles, and vehicle scheduling. These considerations are known as Vehicle Routing Problems (VRP) [2]. Vehicle Routing Problem (VRP) is a problem in constructing the optimal and accurate distribution delivery from one or more depots to many consumers across the areas with the constraint for each service [3]. In its development, VRP standalone can be implemented daily, i.e., when drinking water gallons in Berkah Ro Drinking Water Depot.

This drinking water depot is a drinking water producer, specifically in the drinking water gallon supply and distribution field, by doing the distribution process directly to the customer, such as retailers, Islamic boarding schools, and the home industry. The distribution process of this drinking water company applies a Vehicle Routing Problem model with the characteristics of pick-up and delivery. The company has two fleet vehicles, i.e., a Daihatsu Zebra Espass car with a capacity of 40 gallons and a Tossa motorcycle with a capacity of 16 gallons. Their fleet of vehicles will deliver the drinking water gallon to the customer and, at the same time, pick up the empty gallon to be carried out back to the depot. However, one of the fleets, the Tossa motor, is damaged, so this depot must deliver drinking water gallons with limited

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capacity. The comparison between drinking water gallon demand with the delivered order is shown in **Figure 1**. **Figure 1** illustrates the company's historical data on water gallon orders through WhatsApp, showing unfulfilled demands. Based on the interview result, those unfulfilled demands occur to the customer on the last delivery route and have more empty water gallon pick-up requests than drinking water gallon orders.

According to the interview result and observation, there are two crucial facts. First, the daily demand changes over time, and limited fleets cause unfulfilled demand. Second, there is a subjectivity factor from the driver in determining the delivery priority. It shows that the company is still struggling to determine the optimal distribution route, which increases the risk of higher distribution costs. Based on those two facts, improving and optimizing the distribution route are highly required in the drinking water gallon delivery to reduce the unfulfilled demand and minimize the total distribution cost.

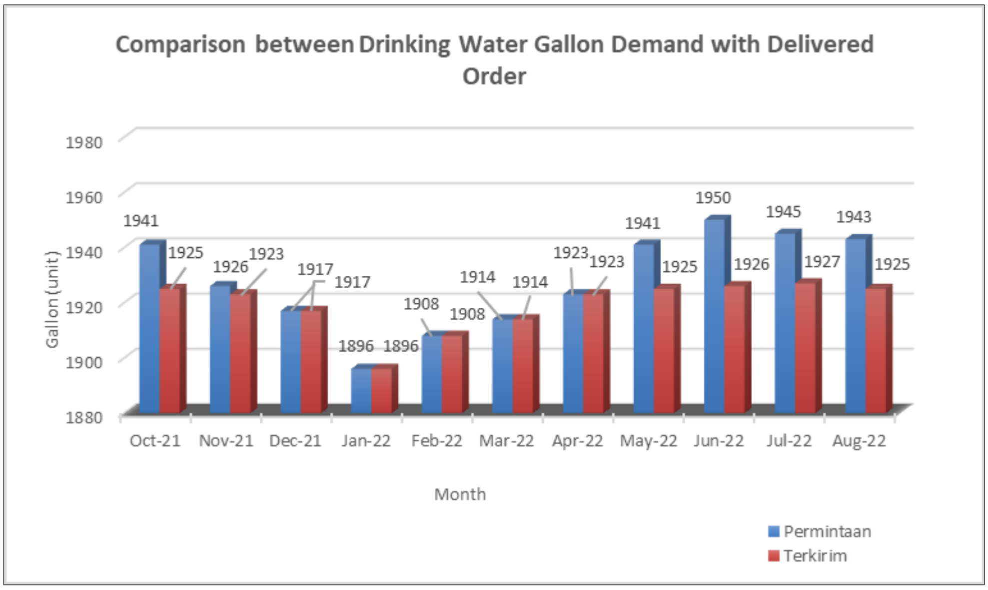

Figure 1 Comparison between Drinking Water Gallon Demand with Delivered Order

2. Material and methods

2.1. Distribution and Vehicle Routing Problem

Distribution is a marketing activity with the purpose of easier delivering the products and services from the producers to customers in order to fulfill customer demand [4]. While according to Zulkarnaen et al. (2020), distribution is an activity of the producer to provide finished goods ready to be delivered to the customers. In the distribution process, an excellent transportation system is required to transfer the product from the production area or warehouse to other locations according to its supply chain stream. The parties involved in the transportation system are the shipper and carrier.

The problem usually occurs to the company is how to distribute to the customer properly and correctly. In several cases, the company that produces the finished goods will directly deliver its products to the customers through the distributor. The distributor then can deliver or sell the products to the retailer or directly to the customers. Thus, a good distribution activity will ease the customers to obtain the desired products, although its producer/factory location is far away [5].

There are several distribution models commonly used for delivering products to customers. However, it requires further understanding to decide on the correct distribution model to maximize the efficiency and effectiveness level of the distribution itself. Those distribution models are as follows [6]:

- Direct shipment

  The distribution model of direct shipment is a distribution type that does not use the services of a distributor and retailer because the producer directly does its distribution processes (transaction and product delivery). This distribution model aims to increase efficiency by minimizing the distribution cost.

- Shipment through transit

  Product shipment through transit is commonly used by the company that requires the assembly of its parts from several suppliers. The distribution model of shipment through transit involves several transit facilities. The transit facilities are managed by the distributor or retailer, whose job is to deliver the products.

- Product shipment through the distributor

  A producer that applies this distribution model will choose the distributor that delivers its products to the customers. The selected distributor has functions of receiving, storage, and distribution as if product shipment from producer to the customers.

- Distribution through decentralization

  A producer that applies this distribution model will place its distributors separately in every area according to its market target. The target is to make the products closer to the customers, elevate customer services, and prevent the inability to fulfill customer demand or stock-out.

- Direct pick-up by the customers

  This distribution activity lets the customers obtain their desired products directly by coming straight to the producer location. The producer gives the products based on a cross-docking system.

Vehicle Routing Problem (VRP) is a problem in designing the optimal and correct distribution delivery from one or more depots to many customers across the areas with the constraints on each service [3]. The development of VRP includes a problem-solving approach and adding new constraints. The research and studies about VRP are continuously evolving following the field's constraints, problems, and actual conditions. Some literature studies are developed to classify VRP into several types and models as follows [7]:

- Capacitated VRP

  Capacitated VRP (CVRP) is the distribution problem that considers the fleet of vehicles' capacity for carrying goods.

- Time-dependent VRP

  The time-dependent VRP model has the characteristics of traveling time between locations depending on the distance. Therefore, the delivery of goods process will highly depend on how far the distance between nodes is.

- Pick-up and Delivery Problem VRP

  This pick-up and delivery VRP have a system that after customers receive the delivered products, other customers' product can also be picked-up to be returned to the depot simultaneously.

- Multi-Depot VRP

  MDVRP has more than one depot and customer that will be visited by one fleet of vehicles. Usually, the fleet of vehicles is located in each depot owned by the company.

- Location Routing Problem

  This VRP type shows that separated depot location and vehicle routing eventually produce sub-optimal solution results and reduce the efficiency of distribution cost. The solution of the LRP model is to provide one or many routes in every available depot.

- Periodic VRP

  Periodic VRP is the characteristics model result of the development of the previous algorithm model. This algorithm aims to solve routing problems with a specific time constraint.

- Stochastic VRP

  A company has stochastic VRP characteristics if there are elements, e.g., random customer demand and travel time.

- Dynamic VRP

  Routing problem with a characteristic of dynamic VRP focuses on the dynamic operation process. This dynamic operation manages the customer demand for some planning period and allocates its demand in real-time to ensure the right fleet of vehicles.

- Inventory Routing Problem

  VRP, with a characteristic of Inventory Routing Problem (IRP), contains the integrity relationship between inventory management and a fleet of vehicles to be dispatched.

- Multi-Echelon VRP

  The characteristics of multi-echelon VRP (MEVRP) focus on the product flow movement in the multi-echelon distribution strategy.

As previously mentioned, VRP, with pick-up and delivery, has a system that after customers receive the delivered products, other similar customers' products will be transported back to the depot simultaneously [7]. Thus, after the fleet of vehicles delivers the goods, it will bring back the customers' non-value products to be returned to the depot or warehouse simultaneously. Mainly the previous research on VRP with pick-up and delivery is classified into three classes following its focus on the problem as follows [8]:

1. VRP with Backhauling (VRPB)

   In a VRP case, with a single demand, all customer deliveries will be served before pick-up activities.

2. VRP with Mixed Pickups and Delivery (VRPMPD)

   A VRP case's delivery and pick-up activities are done simultaneously but separately.

3. VRP with Simultaneous Pickups and Delivery (VRPSPD)

   A case of combined demands in which all delivery and pick-up are done simultaneously in one stop.

Optimization is a branch of old scientific study still being developed regarding technique and application. Optimization itself applies to solving VRP problems with additional constraints or specific characteristics. The constraints can be the time for delivering goods, maximum capacity, obstacles on the way, vehicle speed in certain zones, and many more. Optimization can also mean a pack of information forming the applied mathematical formulation and numerical method to identify the best model from several alternative models without checking and evaluating all alternative models [9]. Several optimization methods to solve VRP are as follows:

- Heuristic

  The heuristic technique is an algorithm strategy for finding the optimal result by trial and error to solve complex problems [10]. Applying the heuristic method helps a company solve optimization problems faster than the exact approach. Examples of heuristic techniques are saving-based, matching-based, and multi-route improvement heuristics.

- Metaheuristic

  The metaheuristic technique is a result-searching method combining the local searching procedure with other more complex local searching strategies to find the general solution. The metaheuristic method forms a procedure usually applied in many problems but still requires modification to ensure the method can be applied according to the problem and constraints [9]. Metaheuristic methods include genetic algorithm, simulated annealing, and tabu search.

The saving matrix method is a method that aims to reduce the saving value from a distance, time, and cost by considering its problem and constraints [11]. The objective function is the distance minimization to the dispatched vehicles that deliver the goods. This method works if every starting node coordinate to each delivery node is known. The four stages of the saving matrix method are:

- Identify the distance matrix
- Identify the saving matrix
- Allocate the customers to the distribution routes
- Sort the customers based on the determined routes

There are several methods to determine the customer route that will be visited as follows [12]:

- Farthest Insert

  This method works by adding the customer to the distribution route. It is repeated continuously until all customers have been inserted in the distribution route. The early stage of applying this method is determining the vehicle route to the farthest customer.

- Nearest Insert

  This method is the opposite of the farthest insert. It is applied continuously until all customers have been inserted in the distribution route. The early stage of applying this method is determining the vehicle route to the nearest customer.

- Nearest Neighbor

  Unlike the previous methods, the nearest method determines the vehicle route from the nearest of the first visited customer. It is applied continuously until all customers have been inserted in the distribution route.

2.2. Model Development Stages

The research flow is arranged in stages and details. The research flow explaining the stages of this research is shown in **Figure 2**.

The early stage in the research is a preliminary study. This early stage aims to study a system in a research object. The preliminary study of this research is studying the distribution system of Berkah RO drinking water company to look further at its current condition and phenomenon. The direct observation at Berkah RO drinking water depot helps identify this company's actual problem. According to the observation result, the research topic is obtained, and the problem is formulated to find the solution or recommendation for improvement through scientific research.

This research aims to acquire Berkah RO drinking water depot's proposed distribution route to minimize the total distribution cost and potential of unmet demand. The purpose of this research should align with the company's vision and the researchers' to get the best solution to the current problem for both parties. The system modeling is designed following the company's problem, an optimal route-solving problem known as Vehicle Routing Problem (VRP). The VRP model developed is based on the pick-up and delivery characteristics with the objective function of minimizing the total distribution cost.

The data collection in this research is classified into two categories based on the data resources as follows [13]:

1. Primary Data

   The primary data is acquired directly from the research object by direct observation and interview. Direct observation is done by observing the actual condition and distribution activities and identifying the problem in the company. The interview is done with the subject of the company's owner and the driver.

2. Secondary Data

Secondary data is the data acquired indirectly from the research object or other in the form of company data or documentation. This research uses the company data, e.g., delivery location, total demand, delivery duration, company's route, and distribution cost, that later would be processed to find the recommendation for improvement.

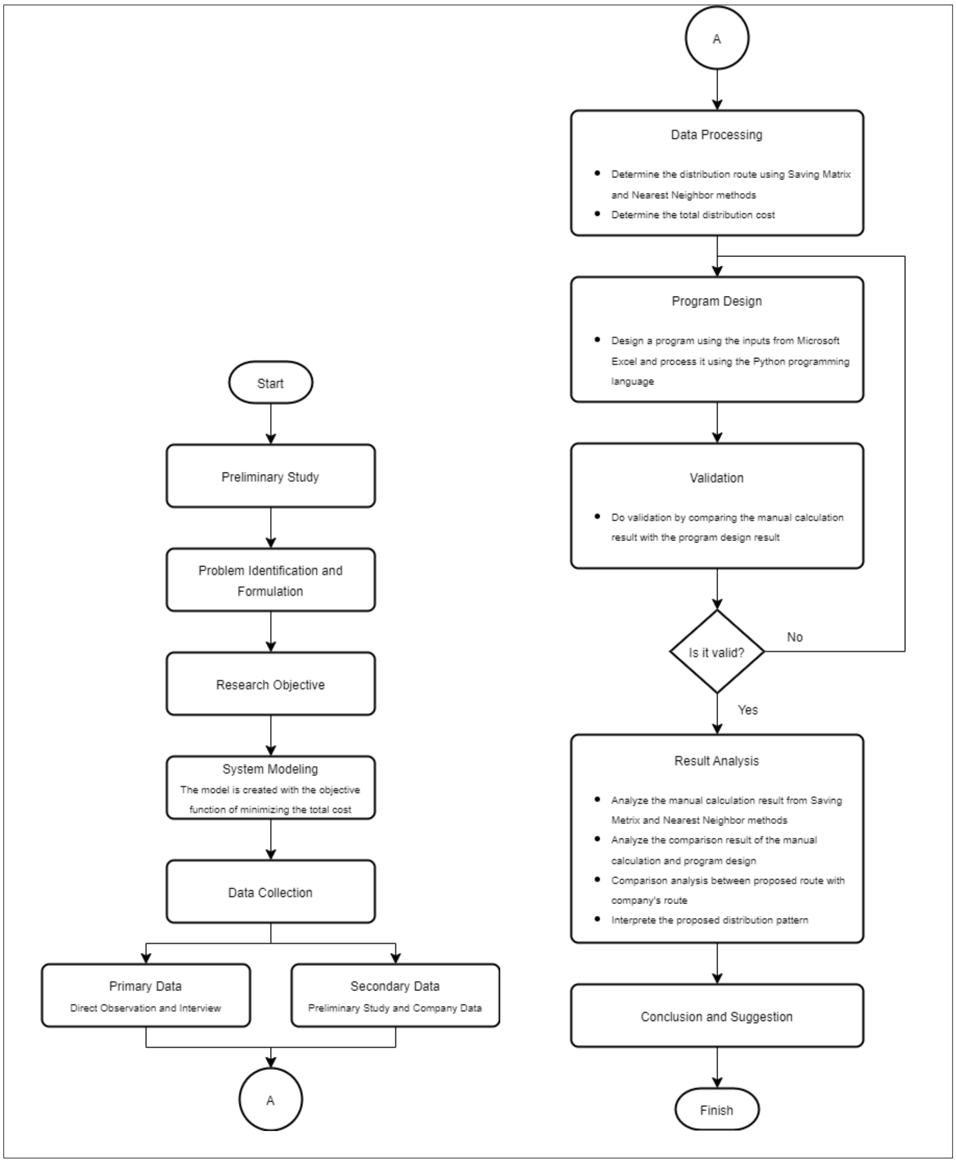

Figure 2 Research Flow

Next is the calculation stage using the saving matrix and nearest neighbor methods. The saving matrix method is applied in the manual calculation. Clarke and Wright first introduce this method. The reason for choosing the saving matrix method is its advantage of the ease of modification based on its problem constraints, i.e., vehicle capacity, total demand, number of vehicles, delivery time, or other constraints to obtain a better result on determining the product delivery schedule [14]. The steps of the saving matrix method are as follows [15]:

- Identify the distance matrix

This step is data collection of distance from the depot (DC) to each customer and between customers in the matrix form the output data from Google Maps with the address input for each customer and depot (DC).

- Identify the saving matrix

The next stage describes the saving or the saving value obtained if there is a combined delivery route from the depot to several customers. The mathematical formulation to obtain the saving value is:

$$S(i,j) = d(G,i) + d(G,j) - d(i,j)$$

Note:

S(i,j) = distance saving
G = depot (DC)
i = the first customer
j = the second customer
d = distance

After obtaining the saving matrix value, the distance saving value is ranked from the largest to the smallest. The result of this stage is the rank and category of each customer

- Allocate all customers to the fleet of vehicles

Allocate the distribution route by considering the fleet of vehicles' capacity and delivery planning time horizon. The designated route also ensures that every customer's delivery and product pick-up request is fulfilled.

- Sort the customer into the designated route

The last stage of this method is to sort every customer based on one trip route. The nearest neighbor method applies for finding out and sorting the customer priority should be served first. This method determines the vehicle route starting from the nearest distance of the first visited customer. It applies continuously until all customer has been inserted into the distribution route.

After obtaining the proposed route result, the overall total cost of the proposed route is calculated. The total cost is calculated by multiplying the total traveled distance with the fuel cost per liter and multiplying it with every vehicle allocated, including the driver cost. Lastly, the total cost is calculated during the distribution process. After the total cost calculation, the program is designed to ease algorithm calculation in considerable numbers and anticipate every changing demand each time. The program design is made of inputs from Microsoft Excel and processed using Python programming to solve the VRP. The reason for using Python programming language is its ease of editing the data, looping calculations, and, hopefully, ease the user in determining the optimal route if there is a changing value on the variable.

The next stage is validation. The validation is made to compare the designed program to the manual calculation and whether the calculation of the designed program fits with the manual calculation result. A review is required to evaluate the model formulation if it is unfit. After data processing, the comparison between the company's and proposed routes will be analyzed. Furthermore, the saving matrix method application will also be analyzed to revise the proposed distribution route. The distribution pattern of product delivery flow in a distribution map through Google Maps helps to read the distribution flow.

This research is based on the actual condition and events of the water gallon distribution activity in Berkah Ro drinking water depot, Cilacap regency. The conclusion and suggestions are given in the last stage of the research. The conclusion is the research results with a solution to a problem to be accountable to the Berkah RO drinking water depot. At the same time, the suggestion is provided for the following research. Considering the research type, this research is classified as descriptive research because describing a phenomenon or event of an actual situation. Descriptive research means research describing and explaining the phenomenon or event in the field [16].

3. Results and discussion

3.1. Pick-up-Delivery VRP Model

3.1.1. Conceptual Model

The conceptual model is constructed to show the relationship between specific variables or factors that influence the research analysis. The conceptual model of this research is shown in **Figure 3.** The output of the problem in this research is to ensure every demand is fulfilled and minimize the distribution cost with the input variables as follows:

- Company Policy

The company sets the maximum limit for vehicle speed as 40 km/hour with the product delivery planning period of 8 hours per day, including a 1-hour break.

- Decision Variable

The decision variable is obtained from the fastest route search result. The number of route and node rank for every optimal route is also obtained to minimize the total traveling distance. After that, the required vehicles are obtained for delivery and pick-up of water gallons.

- Parameter

The parameter is the independent variable that is not influencing other variables, e.g., customer demand, the distance between nodes, service time for each node, and distribution cost.

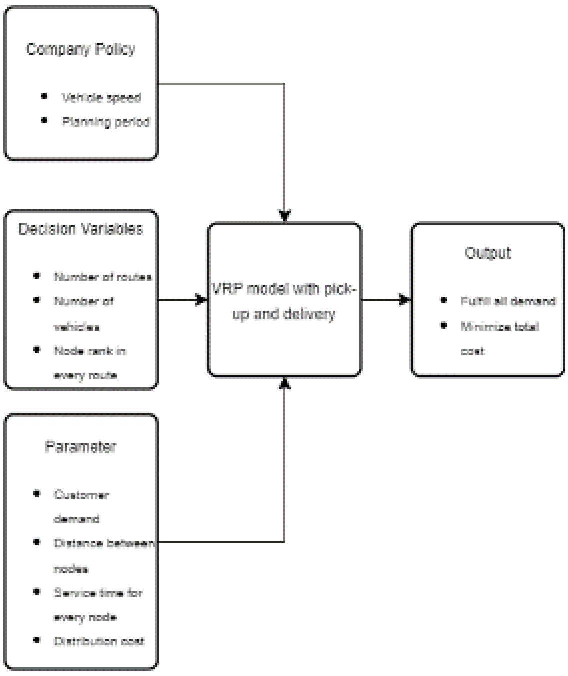

Figure 3 Conceptual Model

3.1.2. System Characteristics

The system in this research focuses on water gallon distribution (homogeneous) from Berkah RO depot to customers, such as retailers, Islamic boarding schools, and the home industry. The system's characteristic is built using Vehicle Routing Problem with pick-up and delivery with a similar product (homogeneous) and the same vehicle capacity. The vehicle will deliver the product to the customer and, at the same time, pick up a similar product with less value from the customer (empty gallon). This research aims to reduce the total distribution cost by searching for the minimum distance based on the time planning horizon and vehicle capacity.

The products are distributed by Daihatsu Zebra Espass cars with a capacity of 40 gallons and an average speed of 40 km/hour. This research applies a daily distribution pattern, once every two days, with the changing daily demand. The longest loading time for a new gallon is 48 seconds per 2 gallons, while for an empty gallon is 15 seconds per 2 gallons. Conversely, the longest unloading time for a new gallon is 36 seconds per 2 gallons, while for an empty gallon is 21 seconds per 2 gallons. The vehicle only serves one time per customer in a one-time delivery route. Furthermore, the total customer demand cannot exceed the vehicle capacity for a one-time delivery route. All the distribution activity starts from the depot and finishes back at the depot.

3.1.3. Mathematical Model

Based on the system characteristic and conceptual model, a new distribution pattern is created based on the following mathematical model:

- Index

i	= location index; $i = 0$ is the depot, $i = 1, 2, \ldots, N$
r	= route index, $r = 1, 2, \ldots, NR_t$
t	= tour index, $t = 1, 2, \ldots, NT$

- Parameter

v	= vehicle speed
$De_{r,t}$	= delivery demand/product delivery at route r, tour t (gallon units)
$Pi_{r,t}$	= pick-up demand/product pick-up at route r, tour t (gallon units)
$WL_{r,t}$	= service time at route r, tour t, (time units)
$WP_{r,t,}$	= traveling time at route r on tour t (time units)
$WLd_{r,t}$	= service time in the depot at route r on tour t (time units)
Q	= vehicle capacity (gallon units)
H	= planning horizon (time units)

- Variables

N	= customer set
$N_{r,t}$	= number of customers at route r on tour t
NV	= total vehicle (units)
NT	= number of tours
NR_t	= number of routes on tour t
NK	= number of company's vehicles (units)
$dist_{r,t}$	= distance at route r, tour t (distance units)
W_l	= total overtime
Lg_i	= loading time for an empty gallon at customer i (total product per time units)
Ulg_i	= unloading time for a new gallon at customer i (total product per time units)
WLg_0	= loading time for a new gallon at the depot (number of products per time units)
$WUlg_0$	= unloading time for an empty gallon at the depot (number of products per time unit)
WP_t	= finishing time for tour t (time units)
W_{pb}	= payment time for every customer
$WB_{r,t}$	= total payment time for every customer at every route (time units)
TWP	= total traveling time (time units)
$M_{r,t}$	= vehicle load at one route, tour t (gallon units)
C_l	= overtime cost
C_G	= driver's salary
C_{bb}	= fuel cost per km
TCD	= total distribution cost
$X_{i,j}$	= binary decision variable, with a value of 1 if the vehicle is traveling on the optimal route, otherwise is 0

3.1.4. Objective Function

The problem in this research is guaranteeing the vehicle load at route r, tour t ($M_{r,t}$) will load the products according to the total delivery and pick-up demand for each customer so that the customer can be fulfilled during the delivery planning time window (H). However, suppose the delivery and pick-up demand was not fulfilled during the delivery plan. In that case, the company's driver will do overtime to fulfill all customer demands. A minimization function of total fulfillment time (TWP) is required to save the delivery time so that the company does not need to spend additional costs for overtime when the delivery time is over the delivery planning time horizon. The objective function in this research is $Min\ F = TWP$. This function has not represented the entire cost that occurred in this system.

3.1.5. Cost Minimization

The cost minimization function is as follows:

$$Min\ F = \sum_{i \in N} \sum_{j \in N} dist_{i,j}\ X_{ij} C_{bb} + NV\ C_g + W_l C_l$$

This function helps decide on the cost due to the previous minimization function. The costs considered in this function are fuel cost, driver's salary, and vehicle rental cost.

3.1.6. Vehicle Optimization

The distribution activities in this company involve multiple trips in that every vehicle can serve one or more customers/routes in a one-time product delivery tour. The number of vehicles is symbolized with (NV). If the solution produces several tours, those tours represent the vehicle requirements (cars). It is because the vehicle can only work during the planning horizon. The statement is written in the following mathematical model:

Number of tours = Number of total vehicles

$$NT = NV$$

A tour has a route set of NR_t to show the number of routes in a tour t by vehicle k. A vehicle route shows the vehicle trip k from the depot to the customers and returns to the depot. The vehicle load in every route ($M_{r,t}$) must be smaller or equal to the total vehicle capacity (Q).

$$M_{r,t} \leq Q\ ,\ \ \forall r = 1, 2, \dots, NR_t; t = 1, 2, \dots, NT$$

The load carried by the vehicle on route t tour t should be less than or equal to the number of delivery ($De_{r,t}$) and pick-up ($Pi_{r,t}$) demand for every customer.

$$De_{r,t} + Pi_{r,t} \leq M_{r,t}\ , \forall = 1, 2, \dots, NR_t; = 1, 2, \dots, NT$$

3.1.7. Total Completion Time Minimization

The tour completion time is when one vehicle finishes one tour with one or several routes. The completion time for every tour is represented by WP_t includes the traveling time for every route ($WP_{r,t}$); service time for every customer on route r ($WL_{r,t}$); and total service time in the depot ($WLd_{r,t}$).

The completion time for each tour = total traveling time for each route + total service time for each customer on route r + total service time in the depot.

$$WP_{t,k} = \sum_{r=1}^{NR_t} WP_{r,t} + \sum_{r=1}^{NR_t} WL_{r,t} + \sum_{r=1}^{NR_t} WLd_{r,t}\ \ , \forall r = 1, 2, \dots, NR_t; t = 1, 2, \dots, NT$$

Traveling time for each route is the total time required for vehicle k on traveling the route r on tour t. The traveling time for each route is obtained from the total distance on route r divided by the vehicle speed.

$$WP_{r,t} = \frac{\sum_{r=1}^{NR_t} dist_{r,t}}{v} \forall r = 1, 2, \dots, NR_t; = 1, 2, \dots, NT$$

On the other hand, the service time for each customer in a route is the total unloading time for a new gallon, the loading time for an empty gallon for each customer, and the total customer payment time on route r.

$$WL_{r,t} = \sum_{i=1}^{N} WULg_i + \sum_{i=1}^{N} WLg_i + WB_{r,t}\ \ , \forall r = 1, 2, \dots, NR_t; t = 1, 2, \dots, NT$$

The customer's payment time on each route is calculated based on the number of visited customers on one route. The total customer payment time = number of customers on route r x the payment time for each customer.

$$WB_{r,t} = N_{r,t} * W_{pb}$$

The service time in the depot consists of the loading time for an empty gallon in the depot added by the unloading time for a new gallon in the depot.

$$WLd_{r,t} = Wlg_0 + WUlg_0$$

The completion time for each tour cannot exceed the planning horizon.

$$WP_t \leq H\ ,\ \ \forall r = 1, 2, \dots, NR_t; t = 1, 2, \dots, NT$$

The total traveling time (TWP) is the sum of all the required completion time for tour t to find the solution.

$$TWP = \sum_{t=1}^{NT} WP_t$$

The overtime is the acquired time if the total product delivery completion time exceeds the time horizon.

The overtime = total completion time – planning time horizon.

$$W_l = TWP - H$$

3.2. Numerical Example

3.2.1. Customer Demand

The data of customer demand given from Berkah RO drinking water depot on June 26th, 2022, used as the sample/dummy for the calculation in the research, can be seen in **Table 1**.

Table 1 Customer Demand Data

No	Customer Name	Delivery	Pick-Up
1	Tahfizh Nurul Ihsan Islamic Boarding School	25	25
2	Gemini Motor	5	7
3	Shop Citra Lestari	3	3
4	Your Own Gym	4	5
5	Mackerel Cracker Manufacturer	11	9
6	Shop Lasmini	3	3
7	"Lanting" Manufacturer	15	12
8	Maju Mapan	3	5
9	Satiman Food Stall	4	3
10	Tempeh Mendoan Producer	10	10
11	Warteg Mulyono	5	6
12	Nyoklat Klasik	4	3
13	Bilqo Sembako Ritail	3	5
14	Warteg Bu Sundoro	4	2

15	Multi Sembako	4	6
16	Rajawali	7	5
17	Shop Nur	3	5
18	Cassava Chips Manufacturer	12	9
19	“Mie Balon” Factory	20	24
20	Junnov Shop	10	8
21	Shop Niaga	4	7
22	Chris Cake	8	8
23	Orphanage Assalam Cilacap	10	10
24	PT Adhimix RMC Indonesia Plant Cilacap	20	20
25	Nurul Iman Islamic Boarding School	15	15

3.2.2. Distance Matrix

The traveling distance is the distance the vehicle travels in delivering water gallons. The distance matrix consists of the distance from the depot to the customer point and between customers. The distance matrix in the unit of a kilometer (km) is shown in **Table 2**.

Table 2 The Distance Matrix

-	DC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
DC	0	12.4	6.9	8.1	7	8.1	10.8	10.4	8.4	8.5	6.4	7.1	6	4.6	4.1	2.9	6	4.8	3.5	5	4.2	4.4	2.3	2.7	10.1	12
1	12.4	0	6	6	6.5	7	8.6	9.6	8	9.3	10.9	7.9	8	9.5	11.1	12.1	11.6	13.9	13.9	15.9	15.1	16.2	14.1	14.5	10.5	9.3
2	6.9	6	0	1.6	2	2.5	4.2	4.9	3.6	5	5	3	2.1	3.6	5.1	6.2	5.7	7.3	7.6	9.2	9.2	10.6	8.6	9	7.1	5.7
3	8.1	6	1.6	0	1.1	1	2.6	3.3	2.7	4	5.8	2.6	2.9	4.4	6	7	6.6	8.3	8.5	10.3	10	11.5	9.6	11.2	8.1	3.3
4	7	6.5	2	1.1	0	1.2	3.6	3.5	2.2	3.5	4.7	1.4	1.9	3.4	5	6	5.5	7.1	7.5	9	9	10	8.6	8.8	4.8	5.8
5	8.1	7	2.5	1	1.2	0	2.5	2.6	2.6	4	5.6	2.5	3.1	4.6	6.1	7.2	6.7	8.3	8.6	10.1	10.1	11.1	9.7	10.2	7.5	4.4
6	10.8	8.6	4.2	2.6	3.6	2.5	0	3.6	4.4	5.8	8	5.1	5.5	7	9	10	8.7	11	10.6	12.1	12.1	13.6	12.1	11.8	5.5	1.1
7	10.4	9.6	4.9	3.3	3.5	2.6	3.6	0	3.6	4.9	6.9	4.6	5.1	6.2	8.2	9.1	8.5	9.4	9.7	11.3	11.3	12.7	11.2	11	5	1.9
8	8.4	8	3.6	2.7	2.2	2.6	4.4	3.6	0	1.3	4	2.1	3	4.1	6	7	5.3	6.6	7.6	8.6	9.2	10.6	9.1	8.9	2.5	7.3
9	8.5	9.3	5	4	3.5	4	5.8	4.9	1.3	0	2.6	2.4	3.2	4.8	5.6	6.7	4	5.2	6.5	7.2	8.2	9.7	8.7	8.5	2.1	7.4
10	6.4	10.9	5	5.8	4.7	5.6	8	6.9	4	2.6	0	3.5	3.2	2.7	3.9	4.9	2.1	3.6	4.8	5.6	6.5	8	7	6.8	3.7	8.8
11	7.1	7.9	3	2.6	1.4	2.5	5.1	4.6	2.1	2.4	3.5	0	1.4	2.4	4.8	6	4.5	6.1	6.5	8	8	9.4	8.7	7.8	4.8	5.8
12	6	8	2.1	2.9	1.9	3.1	5.5	5.1	3	3.2	3.2	1.4	0	1.5	3.9	5	3.9	5.5	5.8	7.4	7.1	8.8	7.3	7.1	5.3	6.8
13	4.6	9.5	3.6	4.4	3.4	4.6	7	6.2	4.1	4.8	2.7	2.4	1.5	0	2.4	3.4	2.3	3.9	4.2	5.7	5.6	7	5.5	6.6	6.4	7.9
14	4.1	11.1	5.1	6	5	6.1	9	8.2	6	5.6	3.9	4.8	3.9	2.4	0	1.4	2.7	3.6	3.3	4.7	4.2	5.3	3.6	3.7	7.7	9.8
15	2.9	12.1	6.2	7	6	7.2	10	9.1	7	6.7	4.9	6	5	3.4	1.4	0	2.8	2.8	2.1	3.5	2.9	4.1	2.3	2.4	8.1	10.6
16	6	11.6	5.7	6.6	5.5	6.7	8.7	8.5	5.3	4	2.1	4.5	3.9	2.3	2.7	2.8	0	2.7	3	4.4	4.6	6.1	5	5	5.5	9.5
17	4.8	13.9	7.3	8.3	7.1	8.3	11	9.4	6.6	5.2	3.6	6.1	5.5	3.9	3.6	2.8	2.7	0	1.2	2	2.9	4.4	3.5	3.3	6.9	11
18	3.5	13.9	7.6	8.5	7.5	8.6	10.6	9.7	7.6	6.5	4.8	6.5	5.8	4.2	3.3	2.1	3	1.2	0	1.8	1.9	3.3	2.2	2	8.1	11.4
19	5	15.9	9.2	10.3	9	10.1	12.1	11.3	8.6	7.2	5.6	8	7.4	5.7	4.7	3.5	4.4	2	1.8	0	1	2.4	3.6	3.1	8.9	13.2
20	4.2	15.1	9.2	10	9	10.1	12.1	11.3	9.2	8.2	6.5	8	7.1	5.6	4.2	2.9	4.6	2.9	1.9	1	0	1.7	2.9	2.4	10	13.1
21	4.4	16.2	10.6	11.5	10	11.1	13.6	12.7	10.6	9.7	8	9.4	8.8	7	5.3	4.1	6.1	4.4	3.3	2.4	1.7	0	2.2	1.7	11.4	14.4
22	2.3	14.1	8.6	9.6	8.6	9.7	12.1	11.2	9.1	8.7	7	8.7	7.3	5.5	3.6	2.3	5	3.5	2.2	3.6	2.9	2.2	0	1	10.4	12.9
23	2.7	14.5	9	11.2	8.8	10.2	11.8	11	8.9	8.5	6.8	7.8	7.1	6.6	3.7	2.4	5	3.3	2	3.1	2.4	1.7	1	0	10.2	12.7
24	10.1	10.5	7.1	8.1	4.8	7.5	5.5	5	2.5	2.1	3.7	4.8	5.3	6.4	7.7	8.1	5.5	6.9	8.1	8.9	10	11.4	10.4	10.2	0	5.4
25	12	9.3	5.7	3.3	5.8	4.4	1.1	1.9	7.3	7.4	8.8	5.8	6.8	7.9	9.8	10.6	9.5	11	11.4	13.2	13.1	14.4	12.9	12.7	5.4	0

3.2.3. Loading/Unloading Time and Cost

The vehicle at Berkah RO drinking water depot company uses for distributing the product is a Daihatsu Zebra Espass car that has been modified with a capacity of 40 gallons. The loading time is the time to load the gallon into the vehicle. The unloading time is the time to unload the gallon at the customer's location. Based on the observation, the longest loading time for a new gallon is 42 seconds per 2 gallons, meanwhile for an empty gallon is 15 seconds per 2 gallons. On the other hand, the longest unloading time for a new gallon is 48 seconds per 2 gallons. Meanwhile, the longest unloading time for an empty gallon is 21 seconds per 2 gallons.

Based on the observation result, the longest time for payment for each customer is 1 minute. The costs included in the distribution cost are as follows:

- The fuel cost for Pertalite is IDR 10,000 per liter (Poerwadi, 2022). One liter of Pertalite can travel 12 km on a modified Daihatsu Zebra Espass car (source: Berkah RO drinking water depot).
- This company applies a daily wage system of IDR 50,000 per day with a meal allowance of IDR 12,000 (source: Berkah RO drinking water depot).
- The overtime cost is IDR 8,000 per hour (source: Berkah RO drinking water depot).

3.2.4. Optimization based on Algorithm

The manual calculation starts with calculating the saving value on each customer point. The saving value calculation result in the form of a matrix based on distance matrix is as follows:

$$S(i,j) = d(G,i) + d(G,j) - d(i,j)$$

Note:

- S(i,j) = saving distance
- G = Depot (DC)
- i = the first customer
- j = the second customer
- d = distance

Based on the saving matrix result, the rank of the customer's point according to the highest to the lowest saving is 6-25-7-3-24-9-5-8-1-4-2-11-10-12-16-13-19-20-17-14-18-21-15-23-22. Determining the vehicle route using the saving matrix method can be described in an algorithm as follows:

Based on the saving matrix calculation result, rank from the largest to the smallest saving value. Then, the vehicle route is created by inserting the customer point with the largest to the smallest saving value to the vehicle route, considering the delivery and pick-up demand to the vehicle capacity. If it exceeds the vehicle capacity, the customer point will be inserted into the route (Ri + 1). Otherwise, if the delivery and pick-up demand does not exceed capacity, the customer point will be inserted into the route (Ri). Next, ensure the route does not exceed the planning horizon of 420 minutes by making the route into the vehicle tour (Ti). If the route exceeds the planning time, then the route will be inserted into the vehicle tour (Ti + 1). Last, ensuring all the customer has been inserted into the route and served by the vehicle. If not, the route construction will return to the early step of inserting the customer into the route.

The proposed optimal vehicle route selection was based on the vehicle route determination algorithm. The vehicle route determination is based on the vehicle capacity of 40 gallons. The rank of the customer to the route based on the largest to the smallest saving value is as follows:

- Route 1

  Based on the saving value rank, the determination of route one is shown in **Table 3**.

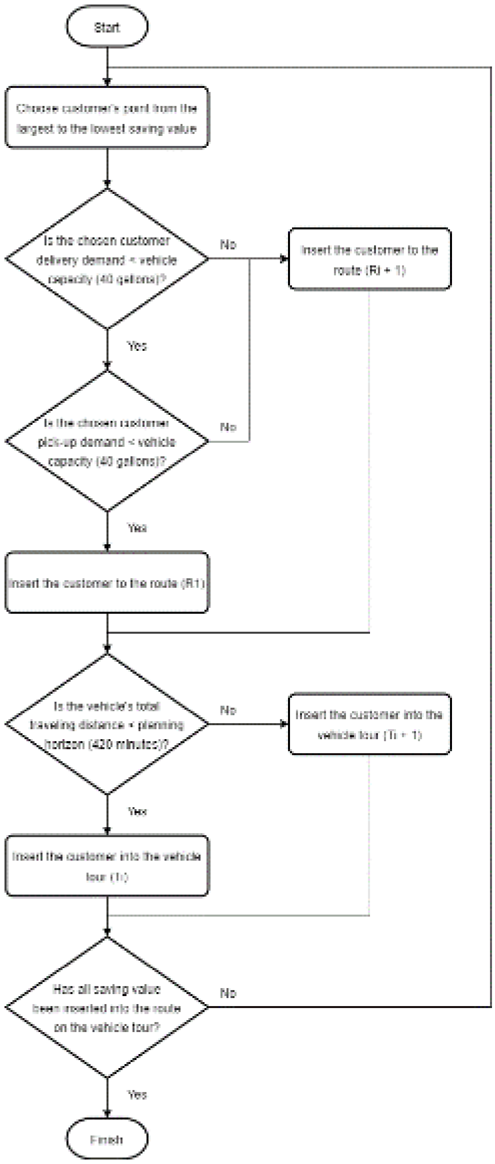

Figure 4 Vehicle Route Determination Algorithm

Table 3 Determination of Route 1

Iteration	Node	Delivery	Pick-up	Capacity
1	DC-6-DC	3	3	40
2	DC-6-25-DC	18	18	40
3	DC-6-25-7-DC	24	23	40
4	DC-6-25-7-3-DC	28	26	40
5	DC-6-25-7-3-24-DC	48	46	40
6	DC-6-25-7-3-9-DC	31	29	40
7	DC-6-25-7-3-9-5-DC	37	35	40
8	DC-6-25-7-3-9-5-8-DC	41	40	40
9	DC-6-25-7-3-9-5-1-DC	62	60	40
10	DC-6-25-7-3-9-5-4-DC	40	39	40

According to **Table 3**, the 5th, 8th, and ninth iterations generated when the 24th, 8th, and 1st customers were inserted to route one caused the load to exceed its vehicle capacity. Thus, the 24th, 8th, and 1st customers are inserted into the following route.

- Route 2

Route 2 continues from the leftover customer point that has not been inserted into the route based on the rank of the largest to the smallest saving value. The determination of route two is shown in **Table 4**.

Table 4 Determination of Route 2

Iteration	Node	Delivery	Pick-up	Capacity
1	DC-24-DC	20	20	40
2	DC-24-8-DC	24	25	40
3	DC-24-8-1-DC	49	50	40
4	DC-24-8-2-DC	29	30	40
5	DC-24-8-2-11-DC	34	33	40
6	DC-24-8-2-11-10-DC	46	45	40
7	DC-24-8-2-11-12-DC	37	35	40
8	DC-24-8-2-11-12-16-DC	42	41	40
9	DC-24-8-2-11-12-13-DC	43	41	40
10	DC-24-8-2-11-12-19-DC	52	50	40

According to **Table 4**, the 3rd, 8th, 9th, 10th, and 11th iterations were generated when the 1st, 16th, 13th, 19th, and 20th customers were inserted into route two. Those cause the load to exceed its vehicle capacity. Thus, the next customer determination is continued until no more gallons can be loaded. The recapitulation result of vehicle route determination based on the vehicle capacity is shown in **Table 5**.

Table 5 Recapitulation of Route Determination based on The Capacity

Route	Node	Demand		Distance (km)
		Delivery	Pick-up	
1	DC-6-25-7-3-9-5-4-DC	40	39	33.3
2	DC-24-8-2-11-12-17-DC	40	37	30.9
3	DC-1-10-DC	37	37	29.7
4	DC-16-13-19-20-14-DC	37	40	23.3
5	DC-18-21-15-23-22-DC	28	27	16.6
Total		182	180	133.8

The next step is allocating all vehicle tour routes by calculating the total completion time. The total completion time is the sum of tour completion time; the total completion time for each tour cannot exceed the planning horizon (420 minutes). If it exceeds, then the new vehicle tour is constructed.

The completion time for one tour = total traveling time for each route + total service time for each customer on route r + total service time in the depot for each route. The tour completion time result is shown in **Table 6**.

Table 6 Tour Completion Time

Tour	Route	Node	Demand (gallon)		Remaining Load Capacity		Total Distance (km)	Total Travelling Time	Duration in The Depot (minutes)	Service Time (minutes)	Total
			Delivery	Pick-up	New Gallon	Empty Gallon					
1	1	DC-6-25-7-3-9-5-4-DC	40	39	0	39	33.3	49.95	20.8250	27.8750	98.65
1	2	DC-24-8-2-11-12-17-DC	40	37	0	37	30.9	46.35	20.4750	26.6250	93.45
1	3	DC-1-10-DC	37	37	0	37	29.7	44.55	19.4250	21.4250	85.4
1	4	DC-16-13-19-20-14-DC	37	40	0	40	23.3	34.95	19.95	24.8	79.7
1	5	DC-18-21-15-23-22-DC	28	27	0	27	16.6	24.9	14.5250	19.5750	59
Total Gallon			182	180	Total Distance		133.8	Total Completion Time			416.2

The node rank for each route uses the nearest neighbor method. This method is applied manually by determining the vehicle route from the nearest distance from the first visited customer. It is repeated continuously until all customers are inserted into the distribution route. One of the steps or algorithms to determining the node for each route using the nearest neighbor is as follows:

- Tour 1 Route 1

Tour 1 Route 1 has the node sequence of DC-6-25-7-3-9-5-4-DC. It starts from the depot and finds the nearest distance from the depot to every customer point shown in **Table 7**.

Table 7 Distance from The Depot to All Customer Points on Route 1 Tour 1

Symbol	Distance from The Depot (DC)
6	10.8
25	12
7	10.4
3	8.1
9	8.5
5	8.1
4	7

According to **Table 7**, the nearest distance is 7 km from the depot to customer point 4. Customer point 4 is the first rank in Route 1 tour 1. Then, the next customer is selected based on the nearest distance starting from customer point 4, as shown in **Table 8**.

Table 8 Distance from Customer Point 4 to The Next Customer on Route 1 Tour 1

Symbol	Distance from The Customer Point 4
6	3.6
25	5.8
7	3.5
3	1.1
9	3.5
5	1.2

According to **Table 8**, the nearest distance is 1.1 km from customer point 4 to customer point 3. Customer point 3 is selected as the second rank on Route 1 tour 1. Then, the next customer is selected based on the nearest distance starting from customer point 3. It is repeated continuously until all point is inserted into the route. The nearest neighbor calculation result is recapitulated based on the node rank for each route, as shown in **Table 9**.

Table 9 Node Rank for Each Route

Route	Node	Distance (km)
1	DC-4-3-5-6-25-7-9-DC	28
2	DC-17-12-11-8-24-2-DC	30.3
3	DC-10-1-DC	29.7
4	DC-14-13-16-19-20-DC	18.4
5	DC-22-23-21-18-15-DC	13.3
Total Distance		119.7

After the node rank for each route is obtained, the recapitulation for optimal vehicle route determination, including the total completion time, is shown in **Table 10**.

Table 10 Recapitulation of Optimal Vehicle Route Determination

Tour	Route	Node	Demand (gallon)		Remaining Load Capacity		Total Distance (km)	Total Travelling Time	Duration in The Depot (minutes)	Service Time (minutes)	Total (minutes)
			Delivery	Pick-up	New Gallon	Empty Gallon					
1	1	DC-4-3-5-6-25-7-9-DC	40	39	0	39	28	42	20.8250	27.8750	90.7
1	2	DC-17-12-11-8-24-2-DC	40	37	0	37	30.3	45.45	20.4750	26.6250	92.55
1	3	DC-10-1-DC	37	37	0	37	29.7	44.55	19.4250	21.4250	85.4
1	4	DC-14-13-16-19-20-DC	37	40	0	40	18.4	27.6	19.95	24.8	72.35
1	5	DC-22-23-21-18-15-DC	28	27	0	27	13.3	19.95	14.5250	19.5750	54.05
Total Gallon			182	180	Total Distance		119.7	Total Completion Time			395.05

3.2.5. Distribution Cost

The distribution cost calculation based on the mathematical model is the cost minimization function as follows:

- Total Fuel Cost

  $\sum_{i\in N}\sum_{j\in N} dist_{i,j}\, X_{ij} C_{bb}$ = total traveling time on the chosen route x fuel cost per liter, which 1 liter of gasoline can travel for 10 km.

  Total fuel cost = $\frac{119{,}7km}{10} \times IDR$ 10,000 = IDR 119,700

- Labor Cost ($NV\ C_g$)

  $NV\ C_g$ = number of vehicles x driver's salary (includes meal)

  $= 1\ \times$ IDR 62,000

  $NV\ C_g$ = IDR 62,000

- Overtime Cost ($W_l C_l$)

he cost occurred if the total completion time over the 8-working hours ($TWP \geq H$)

$W_l C_l$ = the total overtime x overtime cost per hour

$= 0 \times$ IDR 8,000

$W_l C_l$ = IDR 0

Total Distribution Cost = $\sum_{i \in N} \sum_{j \in N} dist_{i,j} X_{ij} C_{bb} + NV\ C_g + W_l C_l$ = IDR 119,700 + IDR 62,000 + IDR 0 = IDR 181,700

4. Result and Discussion

This research is conducted to solve the distribution problem in the drinking water gallon with the VRP model. This problem is solved by constructing the optimal distribution route to fulfill each customer demand. The construction of the proposed optimal distribution route uses the VRP model with pick-up and delivery. Each vehicle delivers the product to the customer point and simultaneously pick-up the other lower value-added product to be carried back to the depot (Lin et al., 2014). The VRP model with this characteristic is implemented in the Berkah RO Depot, which later becomes the research object to determine the optimal route based on that characteristic.

The saving matrix method in determining the route is implemented because of its advantage of modifying according to the problem limitations and constraints, the number of vehicles, the delivery time, and other constraints that can produce a better result in determining the product delivery schedule [17]. This method reduces the saving value from distance, time, and cost by considering the problem and constraints [11]. The optimal route model is determined based on the vehicle capacity and delivery time horizon. In the delivery route, the vehicle will deliver the products according to each customer's demand, and the product load capacity must not exceed the vehicle capacity.

The construction of the proposed optimal route using the saving matrix method starts by making the distance matrix that consists of the distance from the depot to each customer point and the distance between customer points. After that, the saving value is calculated with the formulation S(i,j) = d(G,i) + d(G,j) – d(i,j). **Table 2** shows the distance data obtained by Google Maps, assuming the path is not an alternative path and can be passed by a four-wheeled vehicle. The customer point is ranked based on the largest to smallest saving value, as follows 6-25-7-3-24-9-5-8-1-4-2-11-10-12-16-13-19-20-17-14-18-21-15-23-22.

Table 11 The Result before Node Rank

Route	Node	Distance (km)
1	DC-6-25-7-3-9-5-4-DC	33.3
2	DC-24-8-2-11-12-17-DC	30.9
3	DC-1-10-DC	29.7
4	DC-16-13-19-20-14-DC	23.3
5	DC-18-21-15-23-22-DC	16.6
Total Distance		133.8

The next step is constructing the vehicle route by inserting the customer point with the largest to the smallest saving value into the vehicle route by considering the delivery and pick-up demand to the vehicle capacity. If it has exceeded the vehicle capacity, the customer point will be inserted into the route (Ri + 1). Otherwise, if the delivery and pick-up demand does not exceed capacity, the customer point will be inserted in the route (Ri). The route also must be ensured that it does not exceed the planning time, 420 minutes, by constructing the route as a vehicle tour (Ki). If the constructed route exceeds the planning time, the route will be inserted into the vehicle tour (Ki + 1). Lastly, ensure all customer has been inserted into the route and served by the vehicle. If there is any missed customer, the route construction process will start from the beginning of inserting the customer into the route. The result of determining the route is the input for making the rank of the customer point on each node using the nearest neighbor method to acquire a shorter traveling distance. The total traveling distance before and after node rank is shown in **Table 11** and **Table 12**.

Table 12 The Result after Node Rank

Route	Node	Distance (km)
1	DC-4-3-5-6-25-7-9-DC	28
2	DC-17-12-11-8-24-2-DC	30.3
3	DC-10-1-DC	29.7
4	DC-14-13-16-19-20-DC	18.4
5	DC-22-23-21-18-15-DC	13.3
Total Distance		119.7

According to **Table 11** and **Table 12**, each route 1, 2, 4, and 5 has different distance results, with the shorter result obtained after node rank. Meanwhile, route 3 has no difference. The obtained total distance can be reduced as much as 14.1 km after node rank using the nearest neighbor method. After the node rank, the overall optimal route can be constructed. The recapitulation of optimal vehicle route determination is shown in **Table 13**.

Table 13 Recapitulation of Optimal Vehicle Route Determination

Tour	Route	Node	Demand (gallon)		Remaining Load Capacity		Total Distance (km)	Total Travelling Time	Duration in The Depot (minutes)	Service Time (minutes)	Total (minutes)
			Delivery	Pick-up	New Gallon	Empty Gallon					
1	1	DC-4-3-5-6-25-7-9-DC	40	39	0	39	28	42	20.8250	27.8750	90.7
1	2	DC-17-12-11-8-24-2-DC	40	37	0	37	30.3	45.45	20.4750	26.6250	92.55
1	3	DC-10-1-DC	37	37	0	37	29.7	44.55	19.4250	21.4250	85.4
1	4	DC-14-13-16-19-20-DC	37	40	0	40	18.4	27.6	19.95	24.8	72.35
1	5	DC-22-23-21-18-15-DC	28	27	0	27	13.3	19.95	14.5250	19.5750	54.05
Total Gallon			182	180	Total Distance		119.7	Total Completion Time			395.05

According to **Table 13**, the nearest neighbor method can reduce the total completion time after node rank. The traveling distance reduction on each route causes the completion time for each route shorter than before. Thus, the total gallon delivery completion time is minimized to 395.05 minutes.

4.1.1. Analysis of The Company's Route Compared to The New Route

The company's route is compared with the proposed optimal vehicle route based on the saving matrix and nearest neighbor methods. This analysis shows the change in the optimal result obtained based on the data processing. The company's distribution route is previously constructed based on the driver's subjectivity for deciding the shortest distance from the previous point during the distribution activity. The company's route is shown in **Table 14.**

The company's route takes 146.2 km with a total completion time of 419.95 minutes, but the customer on the last route cannot be served its gallon delivery and pick-up demand. Moreover, one of the company's fleets of vehicles has been damaged, which caused the delivery capacity to be minimal. Meanwhile, the proposed optimal vehicle route in this research applies the saving matrix method to determine the route and tour; and the nearest neighbor method to determine the node rank, minimizing the traveling distance on each route. The proposed optimal vehicle route is shown in **Table 15**.

Table 14 Company's Vehicle Route

Tour	Route	Node	Demand (gallon)		Actual (gallon)		Total Distance (km)	Total Time (minutes)
			Delivery	Pick-up	Delivery	Pick-up		
1	1	DC-24-25-DC	35	35	35	35	27.5	80
1	2	DC-4-3-5-2-7-6-DC	27	26	27	26	32.5	82.8
1	3	DC-1-DC	25	25	25	25	24.8	64.45
1	4	DC-8-9-10-13-12-11-DC	33	31	33	31	27	80.55
1	5	DC-20-21-23-22-DC	24	27	24	27	12.4	48.70
1	6	DC-16-14-15-17-18-19-DC	38	36	23	24	22	63.45
Total Gallon			182	180	167	168	146.2	419.95

Table 15 The Proposed Optimal Vehicle Route

Tour	Route	Node	Demand (gallon)		Actual (gallon)		Total Distance (km)	Total Time (minutes)
			Delivery	Pick-up	Delivery	Pick-up		
1	1	DC-4-3-5-6-25-7-9-DC	40	39	40	39	28	90.7
1	2	DC-17-12-11-8-24-2-DC	40	37	40	37	30.3	92.55
1	3	DC-10-1-DC	37	37	37	37	29.7	85.4
1	4	DC-14-13-16-19-20-DC	37	40	37	40	18.4	72.35
1	5	DC-22-23-21-18-15-DC	28	27	28	27	13.3	54.05
Total Gallon			182	180	Total Travelling Distance	119.7	395.05	182

According to **Table 15**, the proposed route can fulfill all customer demand with a completion time of 395.05 minutes, less than the time horizon of 420 minutes. There is also a saving distance of as much as 119.7 km. It is because the saving matrix method ranks the customer based on the largest to the smallest saving value compared to the company's route. Then, the node rank on each customer using the nearest neighbor method shorten the traveling distance on each route compared to the previous one. Thus, it can be concluded that the proposed route is optimal because it can fulfill the customer demand in less than the distribution delivery time horizon.

The distribution cost is the cost that occurred during the distribution activity. The distribution cost in this company consists of the fuel cost and the driver's salary. The fuel cost is a gasoline price of IDR 10,000 per liter, assuming that 1 liter can travel for 10 km using the company's fleet of vehicles. The driver's salary is IDR 50,000 daily, including a meal allowance of IDR 12,000. The distribution cost comparison between the company's route and the proposed route can be seen in **Table 16**.

Table 16 Distribution Cost Comparison

No	Route Type	Total Distance (km)	Number of Drivers	Distribution Cost
1	Company's Route	142.6	1	IDR 204,600
2	Proposed Route	119.7	1	IDR 181,700

According to **Table 16**, the total distribution cost spent on the proposed vehicle route is IDR 22,900 less than the current company's route. It is because of the shorter traveling distance, which causes cheaper fuel costs. Meanwhile, the driver's salary does not influence the result because the number of drivers is still the same.

4.1.2. Algorithm Implementation on The VRP Application

The software design on determining the optimal vehicle route using a saving matrix and nearest neighbor methods eases the company if there is changing demand for gallon delivery and pick-up. The application is namely VRP-PD application. The application is designed using the PHP programming language. The selection of Python programming language base later the calculation result of this application will be shown in the website form. This program is tested and run using a WAMP server that helps import data and display the optimal vehicle route calculation result on a website.

The display of this application is a local host website that can be accessed through a browser on a personal computer or notebook. The user can import the input data with an extension of .xlsx or Excel file. After running the program, it will display the customer demand, the distance between the depot and the customer, the saving matrix and nearest neighbor calculation result, the time allocation result, and the vehicle route's final result, including the total distribution cost. Then, the validation result is conducted to compare the application result with the manual calculated, which results that it is valid because of no differences.

4.1.3. Pattern Interpretation of The Optimal Distribution Route

Figure 5 Distribution Pattern of Route 1

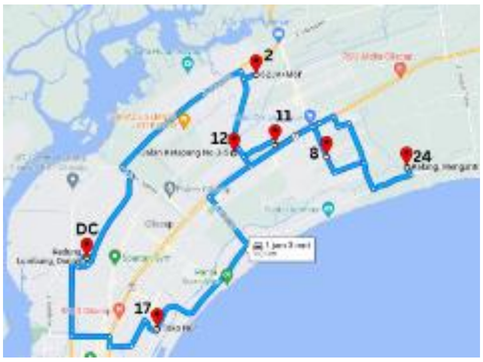

Figure 6 Distribution Pattern of Route 2

Figure 7 Distribution Pattern of Route 3

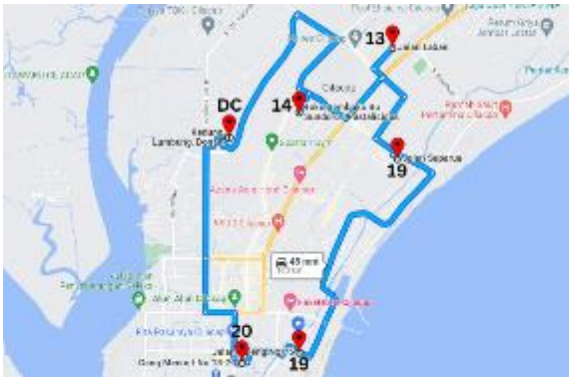

Figure 8 Distribution Pattern of Route 4

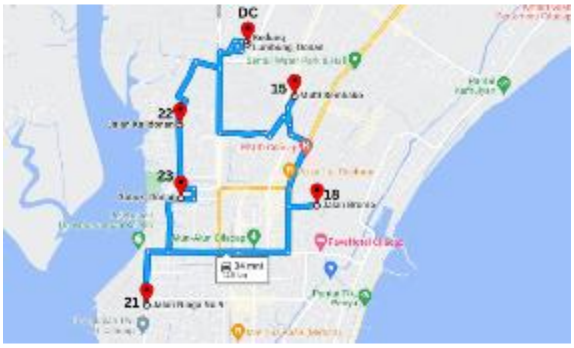

Figure 9 Distribution Pattern of Route 5

Interpreting the distribution pattern aims to show the customer point's distribution map, including the assigned vehicle's route direction. The route distribution pattern is constructed using Google Maps based on the optimal vehicle route calculation result. The optimal distribution pattern of routes 1 to 5 is shown in **Figure 5 to Figure 9**. According to **Figure 5**, route one can serve seven customer points with a total distance of 28 km. Route 2, as shown in **Figure 6,** has five customer points with a total distance of 30.3 km. Meanwhile, route 3 (**Figure 7**) only can deliver to 2 customer points with a total distance of 29.7 km. Lastly, route four and Route 5 (**Figure 8** and **Figure 9**) have five customer points with a total distance of 18.4 km and 13.3 km, respectively.

5. Conclusion

The conclusions of this research are as follows:

- The distribution activity problem at Berkah RO Depot applies Vehicle Routing Problem (VRP) model with a characteristic of pick-up and delivery. The VRP model is solved using a saving matrix and nearest neighbor methods, producing the optimal proposed vehicle route. Based on the calculation result, the optimal route produces a 22.9 km shorter traveling distance than the current company's route. The constructed route also can fulfill all the customer demands during the delivery time horizon.
- The application is designed to solve the Vehicle Routing Problem (VRP) model with a characteristic of pick-up and delivery and can accommodate daily changing demand. The program is based on the saving matrix and nearest neighbor method calculation algorithm. The application has also been verified by comparing it with the manual calculation, producing the optimal vehicle route, total traveling time, and distribution cost. The application's output is the optimal vehicle route for each gallon demand, including the estimated time allocation and total distribution cost.

Compliance with ethical standards

Acknowledgments

We would like to thank the management team of Berkah RO Drinking Water Depot for granting us access to their facility and providing the necessary data and information for this study. Their cooperation and assistance were instrumental in the successful completion of this research. We are also grateful to the Berkah RO Drinking Water Depot staff members for their willingness to participate in interviews and provide relevant input for the analysis. Their firsthand knowledge and experience greatly enriched the findings of this study.

Disclosure of conflict of interest

We declare no conflicts of interest regarding the research and publication of this article, titled "Optimizing the drinking water gallon distribution using vehicle routing problems with pick-up and delivery approach (Case Study of Berkah RO Drinking Water Depot)." We have no financial or personal relationships that could influence or bias the findings and conclusions presented in this article.

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