

# Solving the Capacitated Vehicle Routing Problem with Heterogeneous Fleet Using Heuristic Algorithm in Poultry Distribution

Yulinda Uswatun Kasanah<sup>1a♦</sup>, Nabila Noor Qisthani<sup>1b</sup>, Aswan Munang<sup>2c</sup>

**Abstract.** *The problem that is often experienced in the delivery of goods from distributor to the destination is the delivery route that is not sufficient with the vehicle's capacity. This matter is crucial because it can affect the clients' trust on the shippers in the distributor. This problem can be analyzed using Capacitated Vehicle Routing Problem (CVRP) with Clarke and Wright Algorithm. This research begins with determining the distance between all coordinates with Euclidean Distance, making the distance matrix between places to go. After that, the calculation CVRP using Clarke and Wright Algorithm is executed in this study, a calculate CVRP using Clarke and Wright algorithm can help of Python. The study was conducted at 16 customers coordinates, the results obtained by 4 routes with total load 4751 kg and distance 436 km. Route of delivery the first route 924 kg load and distance 80 km, second route 962 kg load and distance 112 km, third route 1450 kg load and distance 144 km, and the fourth route 1415 kg load and distance 100 km.*

**Keywords:** CVRP, heuristic algoritihm, heterogeneous fleet, Haversin formulae, Python

## I. INTRODUCTION

The development of the poultry industry in the world is increasingly complex and diverse. Various types of products in poultry such as meat, eggs, milk, and life bird are becoming more dynamic from all aspects such as life birds handling, transportation and distribution, and cost efficiency. Knowledge of distribution techniques in a company today is essential. The cost of land transportation is the most significant component in distribution costs, which is 66.8%, the rest is administrative costs and inventory handling costs plus loading and unloading costs, parking, and

illegal levies (Wirabrata, 2013). Meanwhile (Kariyoto, 2016) states that the amount of transportation costs is influenced by the type of haul truck and the amount of cargo loaded by the vehicle. This also affects the live poultry transportation system in the form of broiler chickens (lifebird).

Handling in the distribution of broiler chickens in the form of live (livebird) is a special spotlight in the world of animal husbandry. According to the Poultrysite page, the condition that is the focus of attention in dealing with the distribution of live birds is the occurrence of heat stress or stress in chickens because the environment and temperature is too high. So it takes handling with a particular vehicle when distribute the livebirds. The effect of extreme seasonal changes, such as the rainy season or the long dry season, is a critical period for transporting broiler chickens. In addition, road conditions, distance traveled, and the condition of the broilers themselves are factors in the high mortality rate of chickens during the distribution process (Santos, et al., 2020).

In addition to paying attention to risk conditions during shipping, the components of costs incurred during shipping must be considered. The main element supporting transportation costs is fixed daily delivery

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<sup>1</sup> Logistic Engineering Program, Institut Teknologi Tlekom Purwokerto, Faculty of Industrial Engineering and Design, Institut Teknologi Telkom Purwokerto, Jalan DI Panjaitan 128, Purwokerto 53147.

<sup>2</sup> Industrial Engineering Program, Institut Teknologi Tlekom Purwokerto, Faculty of Industrial Engineering and Design, Institut Teknologi Telkom Purwokerto, Jalan DI Panjaitan 128, Purwokerto 53147.

<sup>a</sup> email: [yulinda@ittelkom-pwt.ac.id](mailto:yulinda@ittelkom-pwt.ac.id)

<sup>b</sup> email: [nabila@ittelkom-pwt.ac.id](mailto:nabila@ittelkom-pwt.ac.id)

<sup>c</sup> email: [aswan@ittelkom-pwt.ac.id](mailto:aswan@ittelkom-pwt.ac.id)

♦ corresponding author

operational costs such as employee salaries, meal allowances, and house fees. Meanwhile, costs that fluctuate and do not always occur during delivery are additional costs such as overtime fees, excess loading fees, handling and storage costs for leftover lifebirds brought back to the depot, and vehicle maintenance costs. In general, the additional costs that occur are often referred as variable costs. Transportation operational costs that will always be incurred and do not change in value are fixed costs.

Furthermore, according to Rabbania et al (2016), various risks that arise when distributing perishable food are influenced by various factors, such as environmental changes, distribution distances, product handling, transportation, and the type of vehicle used. To minimize this risk, Rabbani et al use the Vehicle Routing Problem (VRP) with an exact method by considering multi-middle depots to maintain product quality during distribution and to obtain optimal delivery routes.

In addition to the exact method, algorithms in heuristics and metaheuristics can also be used to determine the best proposed route and reduce product delivery delays.

Based on the research of Wardhana et al. (2019) which uses VRP with Heterogenous Fleet and Time Windows, obtained results in a proposed delivery route with a distance of 22.51% smaller than the route sequence in the existing condition. Chandra & Setiawan used a simulated annealing algorithm, resulting in a distance reduction of 11.79%. While Chandra & Setiawan (2018), use VRP to obtain the fastest distribution route and minimize fuel use.

(Shankar & Reddy, 2018) compared the use of heuristic and metaheuristic methods to solve a logistics company's capacitated vehicle routing problem (CVRP). In their research, Shankar & Reddy suggested that comparing methods between the Holmes and Parker Algorithm (metaheuristic) and the Clarke and Wright algorithm (heuristic) showed different results. Clarke and Wright algorithm produced better results due to its simplicity, greediness and robustness.

To find the fastest route by considering the maximum number of capacities and the allocation

of different lifebird transport vehicles, the Capacitated Vehicle Routing Problem with Heterogeneous Fleet (CVRPHF) method is used. This method is used to overcome a reasonably large problem, in this case the number of routes that are many. Furthermore, to solve the mathematical model, the saving method is used or commonly called the Clarke & Wright Saving Heuristic method which is a method discovered by Clarke and Wright in 1964, which was later published as an algorithm that is used as a solution to the vehicle route problem where a set of routes on each step is swapped to get a better set of routes.

## II. RESEARCH METHOD

Many methods can solve a combinatorial case, either by model simulation or exact methods. This study used an exact method assisted by using python programming to perform calculations with much combinatorial calculation. In general, the steps are taken in this research area, starting from the first step, identifying and observing the distribution flow of the company. Then calculate initial observations regarding requests or orders from each agent/consumer and conduct initial mapping of the distance or coordinates of each agent, depot, and consumer's latitude and longitude.

The second step is to calculate the distance between the consumers using the haversine formula method to form the Matrix distance. The third step is to implement a heuristic algorithm to find the optimal combination of distances routes in python programming using the Google OR-Tools library. The last step is to map the running results with python to provide more precise visualization results.

### Mathematical Model

Adopted from the mathematical model proposed by (Golden et al, 1984) :

$$\sum_{k=1}^T f_k \sum_{j=1}^n x_{0j}^k + \sum_{k=1}^T \sum_{i=0}^n \sum_{j=0}^n c_{ij} x_{ij}^k \quad (1)$$

$$\sum_{k=1}^T \sum_{i=0}^n x_{ij}^k = 1 ; (j = 1, \dots, n) \quad (2)$$

$$\sum_{i=0}^n x_{ip}^k - \sum_{j=0}^n x_{pj}^k = 0 ;$$

$$(k = 1, \dots, T; P=1, \dots, n) \quad (3)$$

$$r_0 = 0 \quad (4)$$

$$r_j - r_i \geq (d_i + a_T) \sum_{k=1}^T x_{ij}^k - a_T ; \quad (5)$$

$$(i = 0, \dots, n; j = 1, \dots, n)$$

$$r_j \leq \sum_{k=1}^T \sum_{i=1}^n a_k x_{ij}^k$$

$$x_{ij}^k \in \{0,1\} \text{ for all } i, j, k ; (j = 1, \dots, n) \quad (6)$$

Where  $n$ = number of customers,  $T$ = number of vehicle types,  $a_k$  = capacity of vehicle type  $k$  ( $a_1 < a_2 < \dots < a_T$ ),  $d_i$ =demand of customer  $j$ ,  $r_j$ = cost of travel from customer  $i$  to customer  $j$ ,  $c_{ij}$ = commodity flow variable associated with customer  $I$ ,  $x_{ij}^k = 1$  if vehicle type  $k$  travels from customer  $I$  to customer  $j$  and  $= 0$  otherwise. The central depot is denoted by  $0$  and  $\sum_{j=1}^n x_{0j}^k$  represents the number of vehicle of type  $k$  used. Therefore, the first double-sum in the objective function (1) gives the total fixed or acquisition cost; the next triple sum gives the total variable or routing cost.

The constraints (2) and (3) ensure that each customer is visited exactly once and that a vehicle arriving at a customer location also leaves that location. The following three sets of constraints (Constrain 4, 5, 6) guarantee that vehicle capacities are not exceeded. The variable  $r_i$  gives the total demand that a vehicle has serviced on its route after it reaches customer  $i$  (the demand customer  $I$  is included). Thus constraint (6) state that the cumulative demand at any customer location is bounded by the vehicle's capacity to serve that customer. The constraint  $r_0 = 0$  and constraint (5) properly define the variable  $r_i$  ( $i = 1, \dots, n$ ). This easily seen after observing that  $\sum_{k=1}^T x_{ij}^k$  equals either 0 or 1. Moreover, these constraints serve subtour-breaking constraints.

### Heuristic Algorithm

In this research, the algorithm used is a heuristic algorithm using a savings algorithm that has been developed by (Clarke & Wright, 1964) or commonly called the Clarke & Wright Saving Algorithm. Saving Algorithm is the most

accessible and most frequently used algorithm to solve various routing problems. The purpose of the savings method is to minimize the total distance traveled by all vehicles and indirectly to minimize the number of vehicles needed to serve all stops (Clarke G. & Wright J. W, 1964).

The Clarke-Wright savings heuristic is one of the best-known heuristics for the VRP. Let  $N = \{1, \dots, N\}$  be the set of customer nodes, and  $0$  be the depot. The distance between nodes  $i$  and  $j$  is denoted by  $c_{ij}$ , and  $c_{0i}$  is the distance of customer  $i$  from the depot. This algorithm describes a randomized version of the heuristic. The basic idea behind this algorithm is that it initially considers a separate route for each customer node  $i$ , and then reduces the total cost by iteratively merging the routes. Merging two routes by adding the edge  $(i, j)$  reduces the total distance by  $s_{ij} = c_{i0} + c_{0j} - c_{ij}$ , so the algorithm prefers mergers with the highest savings  $s_{ij}$ .

This algorithm used two hyper-parameters,  $R$  and  $M$ , which refer to the randomization depth and iteration, respectively. When  $M = R = 1$ , this algorithm is equivalent to the original Clarke-Wright savings heuristic, in which case, the possible merger with the highest savings will be selected. By allowing  $M, R > 1$ , randomization are generated, which can improve the performance of the algorithm further. In particular, this algorithm chooses randomly from the  $r \in \{1, \dots, R\}$  best possible mergers. Then, for each  $r$ , it solves the problem  $m \in \{1, \dots, M\}$  times, and returns the solution with the shortest total distance. Clarke & Wright Saving Algorithm proposed this pseudo-code, as seen in Figure 1.

### Harvesin Method

The haversine formula is a very accurate way of computing distances between two points on the surface of a sphere using the latitude and longitude of the two points. The haversine formula is a re-formulation of the spherical law of cosines, but the formulation in terms of haversines is more beneficial for small angles and distances. (Anisya & Swara, 2017).

One of the primary applications of trigonometry was navigation, and specific

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**Algorithm 1** Randomized Clarke-Wright Savings Heuristic

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1: compute savings  $s_{ij}$ , where
    $s_{ij} = c_{i0} + c_{0j} - c_{ij}$   $i, j \in \mathcal{N}, i \neq j$ 
    $s_{ii} = 0$   $i \in \mathcal{N}$ 
2: for  $r = 1, \dots, R$  do
3:   for  $m = 1, \dots, M$  do
4:     place each  $i \in \mathcal{N}$  in its own route
5:     repeat
6:       find  $k$  feasible mergers  $(i, j)$  with the highest  $s_{ij} > 0$ , satisfying the following conditions:
         i)  $i$  and  $j$  are in different routes
         ii) both  $i$  and  $j$  are adjacent to the depot
         iii) combined demand of routes containing  $i$  and  $j$  is  $\leq$  vehicle capacity
7:       choose a random  $(i, j)$  from the feasible mergers, and combine the associated routes by
         replacing  $(i, 0)$  and  $(0, j)$  with  $(i, j)$ 
8:     until no feasible merger is left
9:   end for
10: end for
11: Return: route with the shortest length

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**Figure 1.** Clarke & Wright Saving Pseudo-code

commonly used navigational formulas are stated most simply in terms of these archaic function names. But you might ask, why not just simplify everything down to sines and cosines? The functions listed above were from a time without calculators, or efficient computer processors, when the user calculated angles and direction by hand using log tables, every named function took appreciable effort to evaluate. The point of these functions is if a table simply combines two common operations into one function, it probably made navigational calculations on a rocking ship more efficient.

A typical calculation for many applications is to find the surface distance (length of geodesic) between two horizontal positions. Even if assuming spherical Earth, calculating the great circle distance between two positions requires several steps to find exactly from latitudes and longitudes. In (Sinnott, 1984) an arcsin expression accurate for small angles is found (assuming spherical Earth). The two expressions for surface distance,  $S_{AB}$ , are (Gade, 2010):

$$\begin{aligned}
 S_{AB} &= \arccos(\sin(\lambda_A) \sin(\lambda_B) + \\
 &\quad \cos(\lambda_A) \cos(\lambda_B) \cos(\mu_A - \\
 &\quad \mu_B)) \cdot r_{roc} \tag{8} \\
 &= 2 \cdot \arcsin\left(\sqrt{\sin^2\left(\frac{\lambda_B - \lambda_A}{2}\right) +} \right.
 \end{aligned}$$

$$\left. \sqrt{+\cos(\lambda_A)\cos(\lambda_B)\sin^2\left(\frac{\mu_B - \mu_A}{2}\right)} \right) \cdot r_{roc} \tag{9}$$

where  $\theta_A, \theta_B$  are the latitude coordinates of point A and the latitude of point B,  $\mu_A, \mu_B$  are the longitude of point A and the longitude of point B,  $S_{AB}$  is the distance,  $r$  is the radius of the sphere.

**Google OR-Tools**

Google Optimization Tools (OR-Tools) is an open-source solver for combinatorial optimization problems. OR-Tools contains one of the best available VRP solvers, which has implemented many 13 heuristics (e.g., Clarke-Wright savings heuristic, Sweep heuristic, Christofides' heuristic and a few others) for finding an initial solution and metaheuristics (e.g. Guided Local Search, Tabu Search and Simulated Annealing) for escaping from local minima in the search for the best solution

In general it is a known fact that its easiest get optimum solutions from Metaheuristics and Holmes and Parker Algorithm but in this present situation Clarke and Wright algorithm produced better results due to its simplicity, greediness and robustness. The Capacitated Vehicle Routing Problem is a challenging unsolved problem and has attracted the attention of several researchers due to its immense practical importance. The savings approach used by the Clarke and Wright

**Table 1.** Distance matrix between customers

|    | 0      | 1      | 2      | 3      | 4      | 5      | 6      | 7      | 8      | 9      | 10    | 11     | 12     | 13     | 14     | 15     | 16     |
|----|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|--------|--------|--------|--------|--------|--------|
| 0  | 0      | 13.063 | 13.395 | 15.492 | 18.423 | 14.539 | 12.983 | 13.189 | 11.757 | 10.906 | 9.043 | 8.319  | 7.787  | 13.619 | 13.641 | 13.597 | 13.585 |
| 1  | 13.063 | 0      | 0.543  | 2.602  | 5.398  | 2.32   | 2.047  | 2.719  | 2.087  | 2.346  | 4.703 | 5.584  | 6.045  | 2.772  | 2.741  | 2.635  | 2.47   |
| 2  | 13.395 | 0.543  | 0      | 2.151  | 5.159  | 2.538  | 1.694  | 2.329  | 2.055  | 2.547  | 5.189 | 6.066  | 6.515  | 3.194  | 3.16   | 3.056  | 2.887  |
| 3  | 15.492 | 2.602  | 2.151  | 0      | 3.437  | 3.079  | 2.826  | 3.067  | 3.84   | 4.589  | 7.302 | 8.184  | 8.646  | 4.328  | 4.284  | 4.205  | 4.051  |
| 4  | 18.423 | 5.398  | 5.159  | 3.437  | 0      | 4.149  | 6.24   | 6.502  | 7.131  | 7.701  | 9.676 | 10.539 | 11.057 | 5.454  | 5.415  | 5.4    | 5.326  |
| 5  | 14.539 | 2.32   | 2.538  | 3.079  | 4.149  | 0      | 4.228  | 4.839  | 4.399  | 4.47   | 5.603 | 6.445  | 6.974  | 1.39   | 1.346  | 1.303  | 1.199  |
| 6  | 12.983 | 2.047  | 1.694  | 2.826  | 6.24   | 4.228  | 0      | 0.687  | 1.267  | 2.285  | 5.697 | 6.51   | 6.87   | 4.818  | 4.788  | 4.681  | 4.516  |
| 7  | 13.189 | 2.719  | 2.329  | 3.067  | 6.502  | 4.839  | 0.687  | 0      | 1.715  | 2.764  | 6.254 | 7.042  | 7.376  | 5.489  | 5.457  | 5.352  | 5.186  |
| 8  | 11.757 | 2.087  | 2.055  | 3.84   | 7.131  | 4.399  | 1.267  | 1.715  | 0      | 1.049  | 4.552 | 5.33   | 5.661  | 4.616  | 4.595  | 4.49   | 4.342  |
| 9  | 10.906 | 2.346  | 2.547  | 4.589  | 7.701  | 4.47   | 2.285  | 2.764  | 1.049  | 0      | 3.523 | 4.286  | 4.612  | 4.362  | 4.351  | 4.252  | 4.128  |
| 10 | 9.043  | 4.703  | 5.189  | 7.302  | 9.676  | 5.603  | 5.697  | 6.254  | 4.552  | 3.523  | 0     | 0.884  | 1.383  | 4.582  | 4.605  | 4.568  | 4.567  |
| 11 | 8.319  | 5.584  | 6.066  | 8.184  | 10.539 | 6.445  | 6.51   | 7.042  | 5.33   | 4.286  | 0.884 | 0      | 0.539  | 5.368  | 5.394  | 5.364  | 5.376  |
| 12 | 7.787  | 6.045  | 6.515  | 8.646  | 11.057 | 6.974  | 6.87   | 7.376  | 5.661  | 4.612  | 1.383 | 0.539  | 0      | 5.906  | 5.932  | 5.901  | 5.912  |
| 13 | 13.619 | 2.772  | 3.194  | 4.328  | 5.454  | 1.39   | 4.818  | 5.489  | 4.616  | 4.362  | 4.582 | 5.368  | 5.906  | 0      | 0.045  | 0.138  | 0.308  |
| 14 | 13.641 | 2.741  | 3.16   | 4.284  | 5.415  | 1.346  | 4.788  | 5.457  | 4.595  | 4.351  | 4.605 | 5.394  | 5.932  | 0.045  | 0      | 0.107  | 0.273  |
| 15 | 13.597 | 2.635  | 3.056  | 4.205  | 5.4    | 1.303  | 4.681  | 5.352  | 4.49   | 4.252  | 4.568 | 5.364  | 5.901  | 0.138  | 0.107  | 0      | 0.17   |
| 16 | 13.585 | 2.47   | 2.887  | 4.051  | 5.326  | 1.199  | 4.516  | 5.186  | 4.342  | 4.128  | 4.567 | 5.376  | 5.912  | 0.308  | 0.273  | 0.17   | 0      |

algorithm can provide reasonable solutions for small size instances. However for large instances calculating the savings may consider large values which affect the solution because the problem solving becomes complex.

### III. RESULT AND DISCUSSION

Life bird distribution system starts from preparing the lifebird in the depot, from the depot every vehicle went to each customer and returns to the depot in final routes. When departing from each depot, each vehicle has loaded a life bird according to the number of orders and has been adjusted to each vehicle capacity. In the existing conditions, each vehicle does not pay attention to the maximum capacity of the vehicle, it only considers the number of orders from each vehicle, this has an impact on the vehicle conditions, especially for engine endurance in the long term condition. In every order delivery, each vehicle over its load as a backup if the customer asks for more life birds than the previous day's order. If there are excess lifebirds left after delivery, the lifebirds will be brought back to the depot.

Model are build based on lifebird distribution system as described above and combined with the method described in research methodology. The research formulation is begin

from compute the distance matrix from latitude and longitude data that obtained from Google Distance Matrix API. The distance between customer node will be calculated using harvesin formula. After the distance matrix had been generated then the model mathematic will be applied to find the optimum route combination that match with constraint in the model mathematic. To running the model with a lot of combinatorial formulation then the model calculation will be conducted using Python with its library to find any possible solution.

#### Distance Matrix Calculation

The distance matrix is obtained from distance calculation based on latitude and longitude coordinates between customers. Each customer's latitude and longitude coordinates are obtained from generating coordinates from google maps. After the customer coordinates are known, the distance between customers will be calculated using the haversine formula to obtain the distance matrix, as shown in the Table 1.

#### Google OR-Tools Using Python

Google OR-tools contains a solver for constraint programming problems, including for solving CVRP problems. There are several options for using heuristic and metaheuristic methods in

OR-tools, such as methods a, b, and c. This study uses the Clark and Wright algorithm to be more compatible for CVRP cases considering heterogeneous fleets.

**Result Summary**

Furthermore, after the long time running to each combinatorial problem, then results are in the Table 2 to Table 4. Each table contains the capacity of the vehicle, the route for each vehicle, the total distance traveled, and the total load of each vehicle. For each vehicle that will depart from the depot will carry a load according to the number of orders from each customer. When there are leftover lifebird after sending it to all custome, then the lifebird will be brought back to

the depot. The number on the route row indicates the customer number and the order amount of each customer that had been delivered. Route 0 shows the depot, route 1 to route 16 shows the identity number of each customer. Load for each customer will be adjusted to the capacity of each vehicle.

From all the The table show that the optimal solution given by the proposed model with the total distance for all routes is 436 KM with total load for all routes is 4751 Kg. Furthermore, this research conduct any comparison between existing model and the improvement one. To get the better visualization the Coding in Python help the plotting graph using matplotlib library. The visualisation of two model shown in Figure 2 and Figure 3.

**Table 1.** Summary result for vehicle 0

| Route for Vehicle 0         |                     |
|-----------------------------|---------------------|
| Vehicle Capacity (Kg)       | 1000                |
| Route                       | 0 11 10 12 0        |
| Load for Each Cust. (Kg)    | 924 189 168 264 303 |
| Distance of The Routes (Km) | 80                  |
| Load of The Routes (Kg)     | 924.2               |

**Table 2.** Summary result for vehicle 1

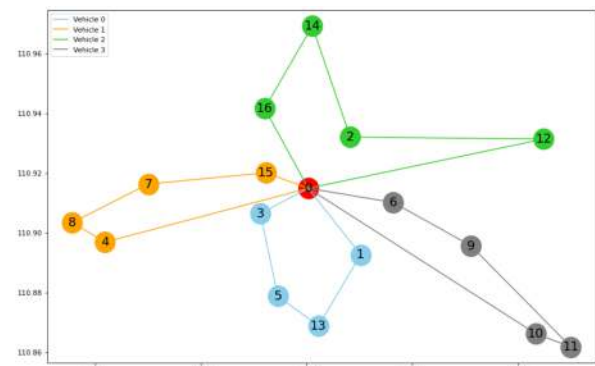
| Route for Vehicle 1         |                          |
|-----------------------------|--------------------------|
| Vehicle Capacity (Kg)       | 1000                     |
| Route                       | 0 14 16 15 13 5 0        |
| Load for Each Cust. (Kg)    | 962 132 65 319 270 176 0 |
| Distance of The Routes (Km) | 112                      |
| Load of The Routes (Kg)     | 962                      |

**Table 3.** Summary result for vehicle 2

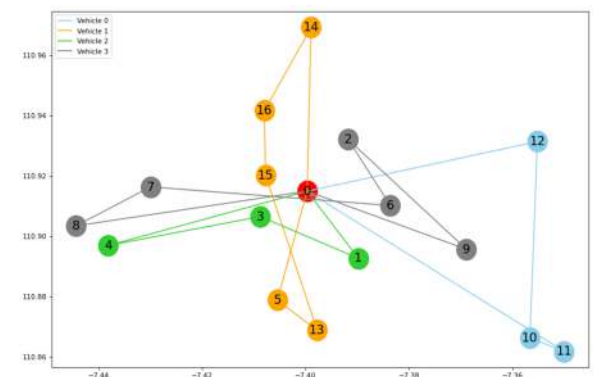
| Route for Vehicle 2         |                     |
|-----------------------------|---------------------|
| Vehicle Capacity (Kg)       | 1500                |
| Route                       | 0 4 3 1 0           |
| Load for Each Cust. (Kg)    | 1450 366 900 168 16 |
| Distance of The Routes (Km) | 144                 |
| Load of The Routes (Kg)     | 1450                |

**Table 4.** Summary result for vehicle 3

| Route for Vehicle 3         |                         |
|-----------------------------|-------------------------|
| Vehicle Capacity (Kg)       | 1500                    |
| Route                       | 0 9 2 6 7 8             |
| Load for Each Cust. (Kg)    | 1415 90 225 460 270 360 |
| Distance of The Routes (Km) | 100                     |
| Load of The Routes (Kg)     | 1415                    |



**Figure 1.** Result plotting existing route



**Figure 2.** Result plotting for improvement route

Figure 2 and 3 show the comparison between existing model and improvement model. The y-axis as Latitude coordinates and the x-axis as longitude coordinates. Form the figure shows there is significant transformation between two

models. Route form Figure 2 shows a more regular route flow. While Figure 3 shows an irregular flow. This is influenced by the use of the harvesin formula which uses static distance mapping. The results will be different if the mapping is done with actual maps. From this mapping, it is sufficient to describe the position of the customer for each coordinate, and can represent the visualization of the entire route of all vehicle.

From the figures, it shown that the route of each vehicle at Figure 2 look more neater then Figure 3. It is affected by the previous lifebird delivery system. before the improvement, the driver only used intuition to deliver the product. they group customers based on the initial estimated distance. In this case, the company did not use certain technologies in product distribution, it only relies on the intuition of truck drivers. In this case, the company has 3 types of live bird transport vehicles, with details of the type and capacity of the vehicle as follows.

Two vehicles have a maximum capacity more than 1500 Kg but in this study, we did not use the listed capacity in the table because the actual condition of the company's vehicle had depreciated its function, so that the actual capacity had been reduced by 10-30% from of its initial capacity. Details of load of each vehicle and the delivery path for each agent/ consumer for each vehicle are shown in the Table 7.

Based on the comparison of the models that have been carried out, it can be obtained the minimization of mileage by allocating the distribution according to the carrying capacity of the vehicle with more optimal results as shown in Table 8.

From the Table 8, it can be obtained a decrease in the total distribution distance of the vehicle's overall distance from the original total mileage of 493,722 KM to 436 KM. when the calculation of operating costs is assumed to be based on mileage only, the reduction in operating costs can be calculated as in Table 9.

The table 9 shows that there is a decrease or savings in fuel costs of Rp 84,129.00 in one day of the lifebird distribution cycle or about Rp 2,523,876.00 per month. The previously shown

**Table 5.** Vehicle's Type and capacity

| Vehicle Type        | Vehicle Capacity | Fleet Number |
|---------------------|------------------|--------------|
| Pickup L300         | 1-1.8 Ton        | 2            |
| Truck Pick-Up       | 0.5-0.8 Ton      | 1            |
| Isuzu Elf NKR 55 CO | 2.8 Ton          | 1            |

**Table 6.** Load of each vehicle and delivery path for each agent existing condition

| Initial Route | Existing Load | Mileage |
|---------------|---------------|---------|
| 0-1-13-5-3-0  | 1514          | 143.184 |
| 0-4-8-7-15-0  | 1406          | 138.654 |
| 0-16-14-2-12  | 876           | 93.96   |
| 0-6-9-11-10-0 | 955           | 117.924 |
| Total         | 4751          | 493.722 |

**Table 7.** Load of each vehicle and delivery path for each agent improvement result

| Improvement Route | Improvement Load | Mileage |
|-------------------|------------------|---------|
| 0-11-10-12-0      | 942              | 80      |
| 0-14-16-15-13-5-0 | 962              | 112     |
| 0-4-3-1-0         | 1450             | 144     |
| 0-9-2-6-7-8-0     | 1415             | 100     |
| Total             | 4751             | 436     |

**Table 8.** Operating cost reduction

| No           | Vehicle Type        | Cost Per Kilometer Distance (Rp/Km) | Initial Distance Cost (Rp) | Improve ment Distance Cost (Rp) | Difference (Rp) |
|--------------|---------------------|-------------------------------------|----------------------------|---------------------------------|-----------------|
| 1            | Truck Pick-Up       | 850                                 | 79866                      | 68000                           | -11866          |
| 2            | Pickup L300         | 680                                 | 80188                      | 76160                           | -4028           |
| 3            | Isuzu Elf NKR 55 CO | 971                                 | 139093                     | 97142                           | -41950          |
| 4            | Pickup L300         | 680                                 | 94284                      | 68000                           | -26284          |
| <b>Total</b> |                     |                                     | <b>393432</b>              | <b>309302</b>                   | <b>84129</b>    |

solutions could be improved, but they represent the first step towards routing solutions, excluding external and traditional distance costs. Another transportation cost were asumming to be fixed cost.

However, when the calculation of transportation costs is considered a variable cost, there are several considerations for adding costs to the distribution of lifebirds, such as providing overtime fees to the driver and assistant of each vehicle. This overtime fee is based on two things.

**Table 9.** Summary estimation of variable and fixed cost

| Vehicle   | Improvement Route | Improvement Load (Kg) | Excess Load (Kg) | Initial Cost (Rp) | Overload Additional Cost (Rp) | Handling and Storage Costs Lifebird Overmeasure (Rp) | Total Additional Cost (Rp) | Fixed Cost (Rp) |
|-----------|-------------------|-----------------------|------------------|-------------------|-------------------------------|--|----------------------------|-----------------|
| Vehicle 1 | 0-11-10-12-0      | 942                   | 303              | 68000             | 55200                         | 1515000  | 1638200                    | 270000          |
| Vehicle 2 | 0-14-16-15-13-5-0 | 962                   | 0                | 76160             | 67200                         | 0  | 143360                     | 270000          |
| Vehicle 3 | 0-4-3-1-0         | 1450                  | 16               | 97142             | 30000                         | 80000  | 207142                     | 270000          |
| Vehicle 4 | 0-9-2-6-7-8-0     | 1415                  | 10               | 68000             | 9000                          | 50000  | 127000                     | 270000          |

First is overtime based on the time of transportation and delivery of lifebirds. The second is based on the number of lifebird loads more than 850 kg for vehicles with a capacity of 1 ton and 1400 kg for vehicles with a capacity of 1.5 tons. For every kilogram of lifebird that exceeds the daily capacity, an additional fee of Rp 30.000,00 per 50 kg of lifebird will be charged.

In addition to the additional overtime fee, there are other additional costs, such as the cost of handling lifebirds that are not shipped and brought back to the depot. For every lifebird brought back to the depot, there will be a charge for handling and storage lifebird with an additional fee of Rp 5,000.00 per kg per day. If the calculation is carried out further, the estimate will be obtained below.

Table 10 shows the total additional costs that come from variable costs. The total variable cost charged for lifebird distribution is Rp 2,115,702.00 in one day of delivery. The total additional cost is obtained from the sum of the initial costs (fuel costs), additional overload costs, and handling and storage costs. This calculation is assumed to be at no cost overtime and maintenance costs and other accidental operational costs that are not directly related to transportation costs.

Fixed costs such as employee salaries and variable costs in calculating the handling and shipping of lifebirds are a particular concern in the poultry industry. The variable costs contribute greatly to the overall daily operational costs. As shown in the table, from the total transportation costs, 66.2% is the variable cost of the total transportation cost per day of Rp 3,195,702.00. The handling and distribution of lifebirds consider various factors in their operations. CVRP with a

heterogeneous fleet using the Clark and Wright heuristic method can accommodate differences in variable costs for each vehicle. This optimization can still be improved by considering other factors such as delivery time limits, the existence of split deliveries, as well as optimizing the replacement of truck types that are tailored to the specifications for handling poultry distribution.

#### IV. CONCLUSION

The study was conducted at 16 customers coordinates, the results obtained by 4 routes with total load 4751 kg and distance 436 km. Route of delivery the first route 924 kg load and distance 80 km, second route 962 kg load and distance 112 km, third route 1450 kg load and distance 144 km, and the fourth route 1415 kg load and distance 100 km. From this calculation it shows the company have savings in fuel costs of Rp 84,129.00 in one day of the lifebird distribution cycle or about Rp 2,523,876.00 per month. Capacitated Vehicle Routing Problem using Clarke and Wright algorithm can provide good solutions for search delivery routes of each vehicle considering the biggest savings and capacity of vehicle. These results can be seen on route breaks with the help of Python programming and Google distance matrix.

CVRP with heterogeneous fleet with the Clark and Wright heuristic method can accommodate the differences in variable costs for each vehicle. Transportation costs accounted for 66.2% of the total transportation operational costs.



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