Minimize transportation cost with clark and wright algorithm saving heuristic method with considering traffic congestion factor

S Kristina¹ and Jason²
¹ Lecturer at Harapan Bangsa Institute of Technology, Bandung-Indonesia
² Assistant Lecturer at Harapan Bangsa Institute of Technology, Bandung-Indonesia

E-mail: sonna@ithb.ac.id

Abstract. Bandung has more than 500 city parks that spread in 5 sectors which need to be maintained. As the department in charge of the city park watering, Diskamtam need to design their daily watering route and schedules to minimize operational costs. The watering route will be designed by using Clark and Wright Saving Heuristic method. By taking into account congestion factors, transportation cost can be minimized, and watering schedule can be developed. Trucks with the capacity of 5,000 litres will be assigned to water every 25 parks in the sector 2 route and the sector 4 route. This study find sector 2 need to be divided into five watering routes and sector 4 need to be divided into 4 watering routes. as a result, there is a 0.83% increase in operational cost. this is due to the congestion factor.

1. Introduction
The transportation system is a system for moving persons or goods consisting of three components: vehicle (equipment), the guide way, and the operations plan according to Steenbrink [1]. Understanding transportation according to Steenbrink [1], transportation is defined as the transfer of people or goods by using vehicles or other tools from and to places that are geographically separated. According to Morlok [2], transportation is the activity of moving or transporting something from one place to another. In general, it can be concluded that transportation is an activity to move something (people and/or goods) from one place to another, either with or without facilities.

The department in charge of the city park watering, Diskamtam need to design their daily watering route and schedules to minimize operational costs. In the previous study conducted by Kristina [3], the route is developed by using a minimum spanning tree method to search routes by only considering the distance between parks with one truck with the capacity of five thousand liters for each sector. The output of the previous study is a watering park schedule and routes. In a real situation, we cannot overrule congestion. Congestion will take a lot of time, so we have to look for other alternative routes that will affect time and cost.

In Bandung, parks spread over five regional sectors. Sector one in the West Bandung region, sector two in the Central Bandung region, sector three in the North Bandung region, sector four in the South Bandung region, and sector five in the East Bandung region. In this study, the calculation of the watering route will be carried out for sector two and four. Diskantam assigned 1 truck for each sector and park in one garage. All trucks must fill out the tank at the deposit. This study is intended to develop the shortest...
watering route with Clark and wright Saving Heuristic method and count in the congestion factor to minimize transportation cost.

2. Literature Review

2.1. Notation

There are several notations used in the calculation process in this study, namely:

- \( T \): Watering location point (m\(^2\))
- \( i \): Number of park location points (\(i=1, 2, \ldots, W\))
- \( W \): Number of partitions of the watering location point (m\(^2\))
- \( Q \): Five thousands litres tank truck capacity (liter/dm\(^3\))
- \( P \): Required watering area per 1.92 water (m\(^2\)/liter)
- \( J_i \): Number of partitions per mileage
- \( B \): Congestion weight
- \( B_1 \): Normal weight (1)
- \( B_2 \): Middle Congestion weight (1.5), Yellow colour
- \( B_3 \): Congestion weight (2), Red colour
- \( Y \): Congestion weight index (\(B_1, B_2, \) and \(B_3\))
- \( JT \): Distance of the city to travel from one point to another
- \( M \): Partition map at distance \(J_i\)
- \( i^{*} \): Partition on a track

2.2. Model Development

This study is based on the earlier two reference studies. The Clark And Wright Saving Heuristic method in determining the shipping route in Agus Purnomo's research [4] and the heuristic algorithm method for route determination based on Muhammad Nashir Ardiansyah's congestion model [5]. In this study, Capacitated Vehicle Routing Problem (CVRP) is utilized to solve the routing problem. This VRP model is selected based on vehicle capacity and trip distance, by including road congestion factors into the equation. After knowing the type of VRP reference model, the next step is to determine the method to solve the problem. In this study, the heuristic method with Clark And Wright Saving Heuristic algorithm (saving matrix method) is utilized to find the optimal travel solution manually. While the Clark And Wright Saving Heuristic reference algorithm is used to calculate the value of the distance savings and the value saved from the actual distance (after including the congestion load factor) with the saving matrix.

The goal is to obtain the distance of each node, the actual distance (after being loaded with the congestion factor), and the minimum costs. The following is a VRP limiting model by using the Clark And Wright Saving Heuristic method to calculate the Total Watering Capacity within the maximum of 2,600 m\(^2\) per route.

Following is the VRP constrain Capacity:

\[
\sum_{i=1}^{M} T_i \leq Q \times P
\]  

(1)

The truck capacity is 5000 litre which are used to watering 2.600 m\(^2\) area. \(W\) cannot exceed 2.600 m\(^2\).

Following are mathematical model For Congestion Weight:

\[
BTK = \sum_{i=1}^{M} \left( \frac{J_i(Y)}{JT} \right) 
\]  

(2)

\[
JT = \sum_{i=1}^{M} (J_i) 
\]  

(3)

2.3. Procedures

There are several procedures or algorithms to calculate transportation costs that have been accumulated with congestion. The following are the steps to determine the shortest route using the Clark And Wright Saving Heuristic method by considering congestion factors such as the following:
1. Find out the maximum vehicle capacity, assuming that each node (location) must be met by the capacity of the vehicle.
2. Develop a distance matrix. This symmetric matrix for a distance from node A to B is equal to the distance of node B to A.
3. Calculate congestion weight between nodes based on the distance range between nodes.
4. Make a congestion distance matrix by multiplying the congestion weight of each node with distance of each node.
5. Calculate the actual distance saving value based on the distance between the depots and nodes and the distance between nodes.
6. Create a distance saving value matrix.
7. Grouping each route based on actual distance saving values based on the largest savings value.

3. Results

The first step in processing data is to take into account the starting point of the water collection site because the square study does not enter into the distance calculation. Before carrying out the calculation process, data collection will be carried out first, which will begin by searching for the distance of each location point with the google maps application and then listed in the distance matrix. From the data collection, the distance from point D to E, point E to F, point F to G, etc., which can be seen in Figure 1 below, uses a sector two-point spacing matrix.

The second step of determining the shortest route will refer to the actual distance after being given the congestion weight. Searching for congestion weights at each location point will be done by looking at the congestion colour for each location point and then calculating it into the mathematical model that has been made. After the calculation is done, a distance matrix will be added, which has been added to the congestion weight on the road so that all the points of distance travelled automatically increase. The following is an example of calculating the congestion weights that can be seen in Figure 1 below:

![Congestion map from Jl. Citarum to Jl. Sentot Alibasyah](image)

**Figure 1.** Congestion map from Jl. Citarum to Jl. Sentot Alibasyah

**Congestion Weight Calculation:**

\[
\text{Weight Calculation} = \frac{(0.2 \times 1 + 0.3 \times 1.5 + 0.6 \times 1)}{1.1} = 1.136
\]

In Figure 1, it can be concluded there was 0.8 km normal traffic and 0.3 km a bit traffic jammed that the actual distance of the location point from Citarum Road to Jalan Sentot Alibasyah are 1,1 km and after being given congestion weight the distance was changed to 1,136 km.

The third step after entering the calculation into the congestion weighting distance matrix for sector two and sector four, the calculation process will be started using the Clark And Wright Saving Heuristic method to obtain the shortest distance of watering on a route. In determining each watering route then the calculation process will find the distance with the largest savings value (the shortest distance).
After getting the watering route with the shortest distance, the next step is to do an optimization by modifying the Clark And Wright Saving Heuristic model in minimizing the route that has been made from the previous stage. This modification aims to minimize transportation costs to be cheaper.

The last step carried out after doing an optimization with the modification of Clark And Wright Saving Heuristic to minimize the route is to modify the watering capacity to be optimal. This calculation is done so that each established route can be minimized again by optimizing the watered area of the study to be closer to 2600 m$^2$ of the route formed. Overall this modification aims to get the route with the shortest distance, the optimal route, and get the optimal watering capacity.

![Figure 2. Matrix Distance Sector 2](image)

In Figure 2, distance between node in sector 2. Node A is truck garage and Node B water depot for fill up the water. Truck start from Node B.

![Figure 3. Congestion Matrix Sector 2](image)
In Figure 3, sector 2 congestion weights that differ from one location point to another. It is assumed that the starting and ending points (B) ignore / do not take into account congestion.

In Figure 4, result congestion matrix multiply with distance matrix.

In Figure 5, result from the saving matrix is obtained from the formula \( S_{ij} = B_{oi} + B_{oj} - B_{ij} \), resulting in the value of the saving matrix for each node. The matrix value is chosen from the largest until a travel route is formed.
In Table 1, it is explained that the formation of a route has been formed based on the order of the matrix of the largest savings value taking into account the watering capacity that does not exceed 2,600 m². In addition the total mileage is accumulated based on distance with congestion rather than conversion of distance calculation from the value of the saving matrix.

Table 2. Comparison of Additional Distance and cost for Sector 2

| Route | Total Distance (KM) | Total Cost (Rp) |
|-------|---------------------|-----------------|
|        | Without Congestion (km) | With congestion (km) | Without Congestion | Without Congestion |
| 1     | 28.07               | 25.8            | 1.934.950         | 1.916.518         |
| 2     | 26.39               | 24.39           | 1.921.126         | 1.904.422         |
| Total | 123.43              | 133.3           | 9.534.482         | 9.6171.150        |
| % Increase | -1.55%              | + 6.32%         | - 0.17%           | + 0.69%           |

Based on the results of the analysis from Table 2, it shows that the total distance in the current study has decreased by 1.55% for calculating distances that do not use congestion and an increase of 6.32% for calculations using congestion, which means a decrease in distance from previous studies for calculations that do not use traffic while experiencing accretion for calculations using congestion.

4. Conclusion
This can be concluded the calculation of the congestion weight affects the distance in sector two so that the distance becomes further but the distance has approached the actual one. In the comparison of routes in previous studies with the current expenditure savings on routes two and five, this is due to low operating costs and shorter distances traveled compared to previous studies.

Mileage with congestion resulted in an increase in operational costs incurred by Diskamtam by 0.69% more than previous study. Whereas study with no use of congestion resulted in savings on routes two, four, and five with previous study so that the costs incurred when not using congestion factors will experience savings of 0.17% cheaper than previous studies. In addition to the above comparison, methods that do not consider congestion and consider congestion result in a total distance difference of 7.87% and a difference in additional costs of 0.86%.

5. References
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