ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25aug1112

Optimization of Routes and Distribution Costs with the Saving Matrix Method and the Floyd-Warshall Method at Amanah Logistik Indonesia (Case Study: Wahdah Water)

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Publication Date: 2025/09/01

Abstract: This study examines the optimization of Wahdah Water distribution routes and costs by Amanah Logistik Indonesia using the Saving Matrix and Floyd-Warshall methods. Saving Matrix produces a distance of 34.3 km with a cost saving of 16.87%, while Floyd-Warshall produces a distance of 36.31 km with a saving of 14.76%. The results show that the Saving Matrix method is more efficient in reducing distance and distribution costs.

Keywords: *Route Optimization, Distribution, Saving Matrix, Floyd-Warshall, Logistics.*

How to Cite: Aidawayati Rangkuti; Afidah Nurwana (2025) Optimization of Routes and Distribution Costs with the Saving Matrix Method and the Floyd-Warshall Method at Amanah Logistik Indonesia (Case Study: Wahdah Water). *International Journal of Innovative Science and Research Technology*, 10(8), 1821-1830. https://doi.org/10.38124/ijisrt/25aug1112

I. INTRODUCTION

Distribution is an important component in ensuring the availability of products in the hands of consumers in a timely and efficient manner. Efficiency in the distribution process not only reduces operational costs, but also increases customer satisfaction and company competitiveness.[23]. Therefore, determining the optimal distribution route strategy is a primary need in the logistics industry.

Amanah Logistik Indonesia is responsible for distributing the Wahdah Water brand of Packaged Drinking Water (AMDK) produced by PT. Berkah Wakaf Indonesia. In its implementation, the company struggles to design an efficient distribution route to reduce the total distance traveled and shipping costs. This condition requires the use of the right route optimization method so that the distribution process can run optimally.

Various approaches have been developed to overcome this problem, including the Saving Matrix and Floyd-Warshall methods. The Saving Matrix method is used to group distribution points based on the potential for distance savings, while Floyd-Warshall is used to determine the shortest path in the distribution network. Previous studies have shown that both methods are effective in optimizing distribution routes in various sectors.[10].

This study aims to apply the Saving Matrix and Floyd-Warshall methods in optimizing routes and distribution costs at Amanah Logistik Indonesia. In addition, a comparison of the effectiveness of the two methods in reducing total distance traveled and distribution costs is carried out. The results of this study are expected to provide real contributions to companies in designing more efficient distribution systems and become references for similar research in the field of logistics.

II. LITERATURE REVIEW

- *Travelling Sallesman Problem (TSP)*

Travelling Salesman Problem (TSP) is one of the classic problems in combinatorial optimization, where a salesman must visit all cities exactly once and return to the city of origin with a minimum total distance.[16]. This problem is widely applied in logistics to determine efficient distribution routes.

- *Mathematically, TSP can be Formulated as Follows*

✓ *Decision Variables:*

$$x_{ij} = \begin{cases} 1, \text{ if the route from city } i \text{ to city } j \text{ is selected} \\ 0, \text{others} \end{cases}$$

✓ *Objective Function:*

$$\min z = \sum_{i=1}^{N}\sum_{j=1}^{N} c_{ij}x_{ij}$$

Where c_{ij} is the distance or travel cost from city i to city j.

- *Limitations:*

✓ *The Salesman Visits Each City Exactly Once.*

$$\sum_{i=1}^{N} x_{ij} = 1, j = 1,2, \dots, N$$

✓ *The Salesman Passes Through Each City Exactly Once.*

$$\sum_{j=1}^{N} x_{ij} = 1, i = 1,2, \dots, N$$

✓ *Subroute Constraints that Ensure there are no Subroutes (Round Trip within a Small Portion of the City)*

$$u_i - u_j + Nx_{ij} \leq N - 1$$

$$i \neq j, i = 2, \dots, N, j = 2, \dots, N, \quad u_i, u_j \geq 0$$

- *Information:*

min z : Objective Function

x_{ij} : Distance from city i to city j

i : Starting City

j : Destination City

➢ *Vehicle Routing Problem (VRP)*

Vehicle Routing Problem (VRP) is a problem of optimizing vehicle routes from depots to customers with the aim of minimizing distance or distribution costs. VRP is a development of the Traveling Salesman Problem (TSP) by considering several important elements, namely depots, customers, drivers, and vehicle routes. [14]. VRP also involves constraints such as vehicle capacity, service time windows, number of vehicles, and geographical constraints.

Some commonly used VRP variants include: VRPMT (Vehicle Routing Problem with Multiple Trips), VRPTW (Vehicle Routing Problem with Time Windows), VRPPD (Vehicle Routing Problem with Pickup and Delivery), CVRP (Capacitated Vehicle Routing Problem), VRPMP (Vehicle Routing Problem with Multiple Products), VRPMD (Vehicle Routing Problem with Multiple Depots), PVRP (Periodic Vehicle Routing Problem), VRPHFV (Vehicle Routing Problem with Heterogeneous Fleet of Vehicles), SVRP (Stochastic Vehicle Routing Problem), and DVRP (Dynamic Vehicle Routing Problem).

➢ *Capacitated Vehicle Routing Problem (CVRP)*

Capacitated Vehicle Routing Problem (CVRP) is an extension of the Vehicle Routing Problem (VRP) that considers vehicle capacity limits. The main objective of CVRP is to determine the optimal route with minimum cost, where each vehicle serves a number of customers without exceeding its load capacity.[9].

- *The Mathematical Formulation of CVRP is as Follows:*

✓ *Objective Function:*

$$Min\ z = \sum_{k\in K}^{n}\sum_{i\in J_0}^{n}\sum_{j\in J_0}^{n} c_{ij}\, x_{ijk}$$

- *With the Following Constraints:*

✓ *Each Customer is Visited Exactly Once by One Vehicle.*

$$\sum_{j\in J_o}^{n}\sum_{k\in K}^{n} x_{ijk} = 1,\ i \in J_o$$

✓ *Total Demand for all Points in a Route does Not Exceed Vehicle Capacity..*

$$\sum_{i\in J_o}^{n}\sum_{j\in J_o}^{n} D_j x_{ijk} \leq Q_k\,,\ \ k \in K$$

✓ *Every Route Starts from Depot Zero.*

$$\sum_{j\in Jo}^{n} x_{ojk}\,, \quad k \in K$$

✓ *Every Vehicle that Visits a Point will Definitely Leave that Point.*

$$\sum_{i\in J}^{n} - \sum_{j\in J}^{n} x_{ijk} = 0, \quad k \in K$$

✓ *Each Route Ends at a Depot.*

$$\sum_{i\in J_o}^{n} x_{i0k} = 1, \quad k \in K$$

✓ *The Variable x_{ijk} is a Binary Integer Variable.*

$$x_{ijk} \in \{0,1\}, (i, j \in J_o, k \in K)$$

- *Information:*

i : Location index, i = 0 is depot, i = 1,2, … , n are consumers.

k : Vehicle index, k = 1,2, … , m

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25aug1112

c_{ij}: Travel distance from consumer i to consumer j

n : Number of consumers

D_j : Number of requests sent $j \in J$

Q_k : Vehicle capacity k

K : Vehicle pool

J : Set of customers, $J = \{1,2,\ldots,n\}$

J_o : Set of all nodes including depots, $J_0 = \{1,2,\ldots,m\}$

y_i and y_i:Variables used to avoid subtours, can be interpreted as the position of node $i, j \in J$ in a route.

➢ *Saving Matrix Method*

The Saving Matrix method is a heuristic approach to solving the Capacitated Vehicle Routing Problem (CVRP). The goal is to minimize the distance and distribution costs by combining several delivery points in one vehicle route with limited capacity.[19]. This process helps companies save operational costs and optimize vehicle usage.

- *The Stages of this Method Include:*

✓ *Distance Matrix:*

Compile a distance matrix between locations based on actual data or the Euclidean formula:

$$Dist\ (A,B) = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

If available, actual distance is recommended as it reflects real conditions.

✓ *Saving Matrix:*

Calculates the potential distance savings if two customers are combined into one route:

$$S(x,y) = J(G,x) + J(G,y) - J(x,y)$$

✓ *Vehicle and Route Allocation:*

Savings values are sorted from largest to smallest. Combinations with the largest savings are prioritized in route formation.

✓ *Determining the Order of Visits:*

Once the route has been established, the order of visits is optimized using algorithms such as:

- Nearest Neighbor, which selects the next closest point gradually.
- Nearest Insertion, which inserts points into the route based on the most efficient position.

➢ *Floyd-Warshall Method*

The Floyd-Warshall algorithm is a dynamic programming algorithm used to find the shortest distance between all pairs of vertices in a directed and weighted graph, as long as there are no negative cycles.[3]. This algorithm was developed separately by Stephen Warshall for transitive closure and Robert Floyd for shortest paths in 1962, but due to the similarity of structure, both are known as the Floyd-Warshall algorithm.

- *Floyd-Warshall Algorithm Steps:*

✓ Create nodes on the map and represent each location point as a node.

✓ Compile the initial matrix table: Compile the initial matrix based on the distance between nodes. If there is no path, the distance value is filled with ∞ (infinity).

✓ Perform iteration: For each node k, a comparison is made: According to Ramadhani, in general the Floyd-Warshall algorithm is as follows.[8]:

$$X = X_0$$

For $k = 1$ until n, do:

For $i = 1$ until n, do:

For $j = 1$ until n, do:

If $X[i,j] > X[i,k] + X[k,j]$

Swap $X[i,j]$ with $X[i,k] + X[k,j]$

$$X^* = X$$

The values in the matrix are updated if a shorter path through node k is found.

✓ *Determining the Optimal Route:*

The final result is a minimum distance matrix between all nodes which can be used to determine the optimal distribution route.

III. RESULTS AND DISCUSSION

This study examines the distribution of Wahdah Water by Amanah Logistik Indonesia from a warehouse in Tallasa City to customers in Biringkanaya District. Distribution is carried out using three box cars with a capacity of 130 units, but the route is not yet efficient. Data were obtained through observation and recording of requests.

Table 1 Distribution Data for Biringkanaya District

No	Customer Name	Code	Average Request (Unit)
1	Toko H.Gani	C1	80
2	Catering Warda	C2	50
3	Toko Berkah	C3	34

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4	Toko Baru Tiga	C4	15
5	Marewo Bakery	C5	9

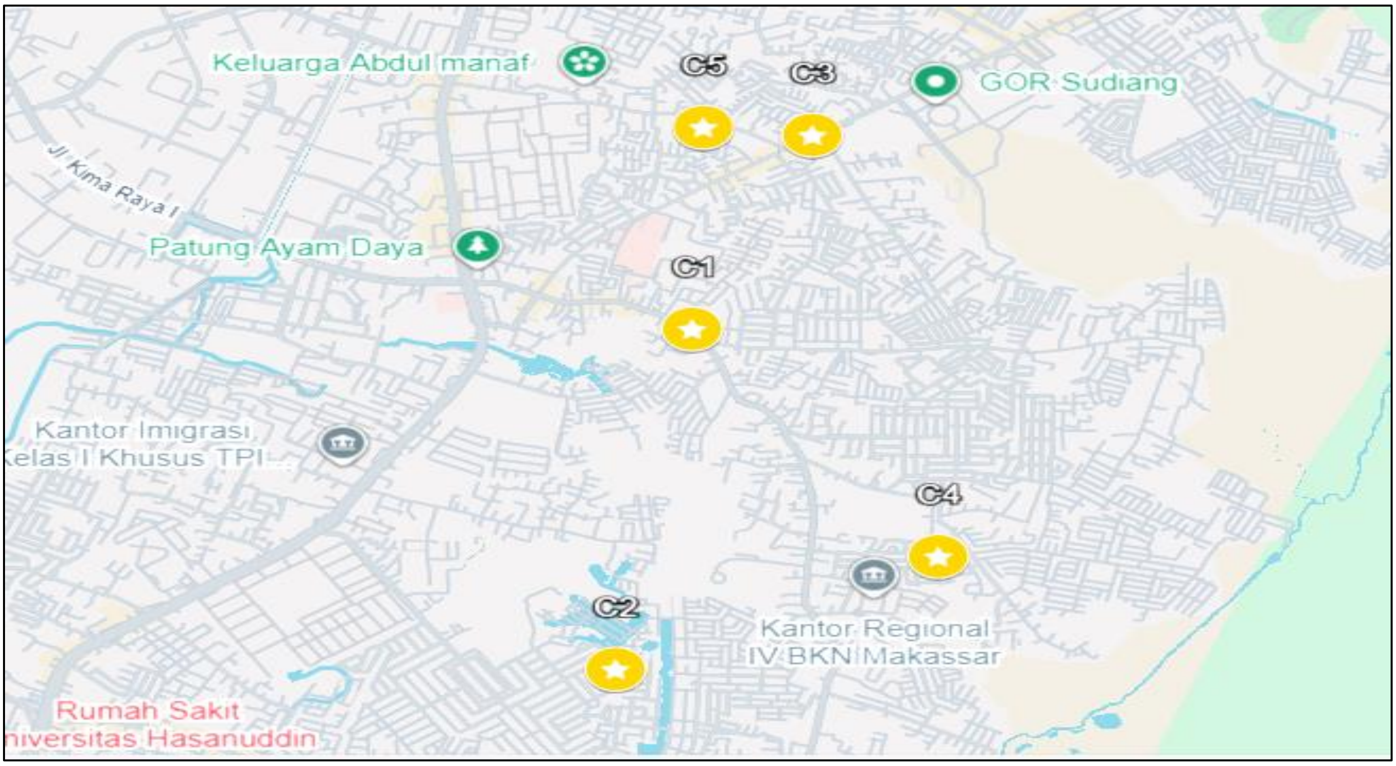

Fig 1 Research Location Map

Table 2 Initial Company Route Data, Total Distance and Total Demand

No	Initial Route	Total Distance (Km)	Total Demand (Unit)
1.	G-C1-C4-G	20,6	95
2.	G-C2-G	16,2	50
3.	G-C5-C3-G	13,6	43
TOTAL		**50,4**	**188**

Distribution Costs of Rp317,000.00 per Month were Obtained.

➢ *Implementation of Saving Matrix Method*

- *Step 1 Identify and Define the Distance Matrix*

Table 3 Distance Matrix in Km Unit

Code	G	C1	C2	C3	C4	C5
G	0					
C1	7,0	0				
C2	8,1	3,3	0			
C3	6,6	1,8	4,6	0		
C4	10	1,7	2,7	2,7	0	
C5	6,3	1,8	4,5	0,5	3,5	0

In Table 3, it was obtained and collected using the Google Maps application.

- *Step 2 Identifying and Determining the Saving Matrix using the Formula, Namely:*

$$S(x,y) = J(G,x) + J(G,y) - J(x,y)$$

✓ *Calculation Example:*

$$S(C1,C2) = J(G,C1) + J(G,C2) - J(C1,C2)$$

$$= 7{,}0 + 8{,}1 - 3{,}3 = 11{,}8$$

The calculation is continued for each customer, until the following Saving Matrix Table is obtained:

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25aug1112

Table 4 Savings Matrix in Km Units

Code	C1	C2	C3	C4	C5
C1	0				
C2	11,8	0			
C3	11,8	10,1	0		
C4	15,3	15,4	13,9	0	
C5	11,5	9,9	12,4	12,8	0

In Table 4 Saving Matrix, where the value of 11.8 km is placed in the second column, namely C1, and the third row, namely C2.

- *Step 3 Allocate Vehicles and Routes Based on Location*

To simplify the process of allocating customers to vehicles and determining routes, a table can be prepared that displays the largest value of the saving matrix. The allocation of customers to vehicles and routes is obtained:

- ✓ Vehicle 1 consists of customer routes C2, C4, C3 and C5.
- ✓ Vehicle 2 consists of customer route C1.

- *Step 4 Sort Consumers into Predefined Routes*

Table 5 Distribution Route Using the Nearest Neighbor Method

Route	Alternative Route	Distance (Km)	Total Distance (Km)
C2,C4,C3 and C5	G-C5-C3-C4-C2-G	6,3+0,5+2,7+2,7+8,1	20,3
C1	G-C1-G	7,0+7,0	14,0

The results of this optimization produce a total distance of 34.3 km with a distribution cost of Rp264,336.00.

➢ *Implementation of Floyd-Warshall Method*

- *Step 1 Creates Nodes on the Map and Represents Each Location Point as a Node.*

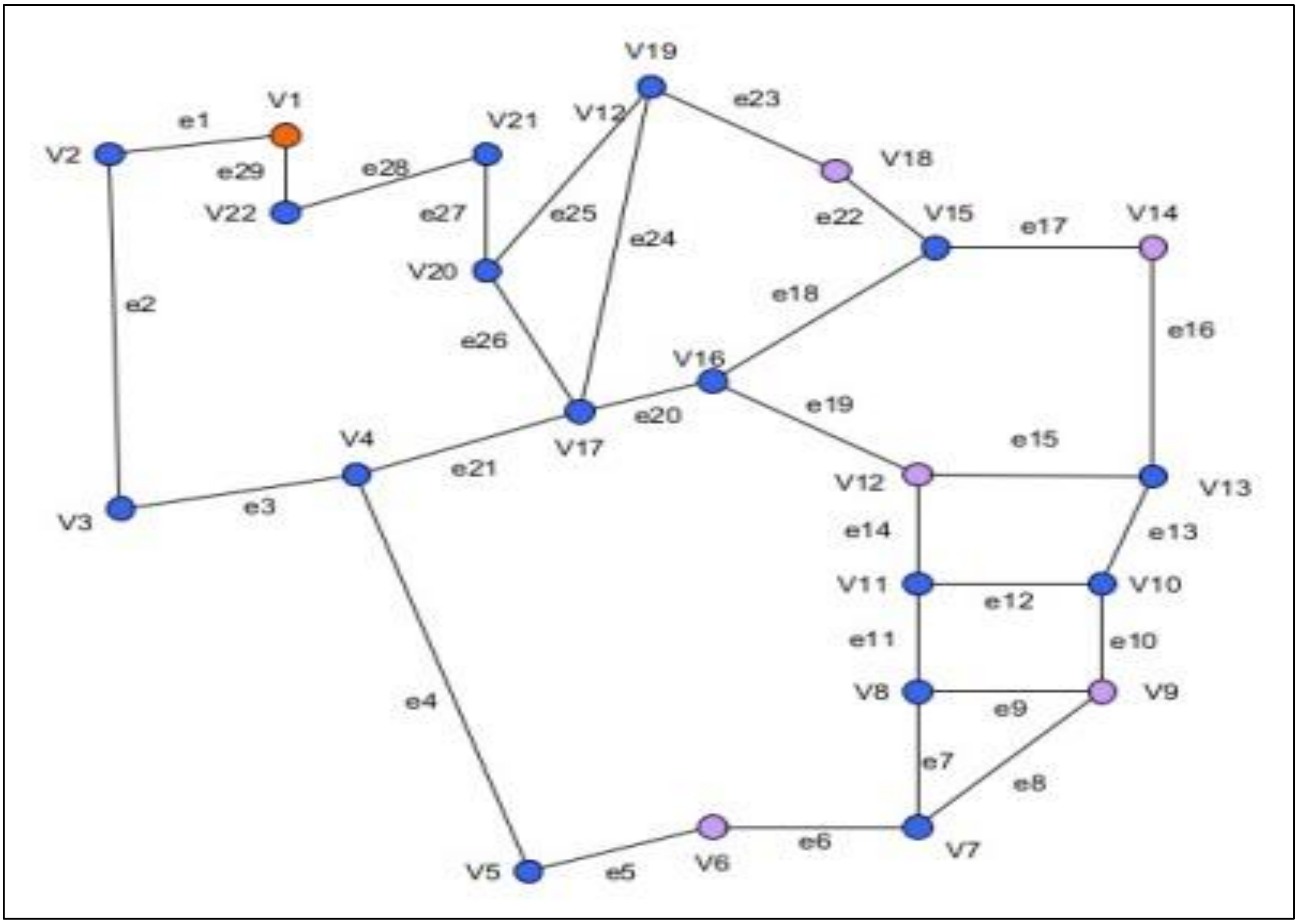

Fig 2 Research Area Graph

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25aug1112

Table 6 Node Representation of Location Points

Node	Location Name
V1	Gudang Wahdah Water
V2	Simpang Jl.Jalur Lingkaran Barat
V3	Simpang Jl.Perintis Kemerdekaan
V4	Simpang Jl.Telkomas
V5	Simpang Jl.Telkom I
V6	Warda Catering
V7	Simpang Jl.Paccerakkang
V8	Simpang Jl.Poros Mangga Tiga
V9	Toko Baru Tiga
V10	Simpang Jl.Tamalaba Mangga Tiga
V11	Simpang Jl.Paccerakkang
V12	Toko H.Gani
V13	Simpang Jl.Poros Hartako
V14	Toko Berkah
V15	Simpang Jl.Sanrangan
V16	Simpang Jl.Pajjaiang
V17	Simpang Jl.Kimia Raya I
V18	Marewo Bakery
V19	Simpang Jl.Kimia Raya II
V20	Simpang Jl. Kapasa Raya
V21	Simpang Jl.Kw. Pergudangan dan Industri Parangloe
V22	Simpang Jl. Jalur Lingkaran Barat

- *Step 2 Constructing the Initial Matrix Table*

Table 7 Floyd-Warshall Algorithm Initial Matrix

	V1	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**	**V8**	**V9**	**V10**	**V11**
V1	0	0,66	∞	∞	∞	∞	∞	∞	∞	∞	∞
V2	0,66	0	5,88	∞	∞	∞	∞	∞	∞	∞	∞
V3	∞	5,88	0	1,41	∞	∞	∞	∞	∞	∞	∞
V4	∞	∞	1,41	0	1,10	∞	∞	∞	∞	∞	∞
V5	∞	∞	∞	1,10	0	0,52	∞	∞	∞	∞	∞
V6	∞	∞	∞	∞	0,52	0	1,64	∞	∞	∞	∞
V7	∞	∞	∞	∞	∞	1,64	0	0,55	1,01	∞	∞
V8	∞	∞	∞	∞	∞	∞	0,55	0	0,46	∞	0,44
V9	∞	∞	∞	∞	∞	∞	1,01	0,46	0	0,43	∞
V10	∞	∞	∞	∞	∞	∞	∞	∞	0,43	0	0,54
V11	∞	∞	∞	∞	∞	∞	∞	0,44	∞	0,54	0
V12	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	0,81
V13	∞	∞	∞	∞	∞	∞	∞	∞	∞	1,11	∞
V14	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
V15	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
V16	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
V17	∞	∞	∞	1,80	∞	∞	∞	∞	∞	∞	∞
V18	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
V19	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
V20	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
V21	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
V22	0,41	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞

Based on Table 7, the $X_{i,j}$ is the initial matrix of the Floyd-Warshall algorithm. Then the calculation process is carried out with the Floyd-Warshall algorithm to find the smallest weight between all points, where the smaller the weight, the more optimal the route.

- *Step 3 Perform Iterations, Starting from Iteration 1 to Iteration n.*

Perform calculations for a 22×22 matrix with the Floyd-Warshall algorithm.

✓ *Calculation Example:*

Iteration $k = 1$

For each cell of the matrix X_0 check whether $X[i,j] > X[i,k] + X[k,j]$. If yes, then swap $X[i,j]$ with $X[i,k] + X[k,j]$.

✓ *Calculation :*

- $X[1,2] = 0{,}66$ and at $X[1,1] + X[1,2] = 0 + 0{,}66 = 0{,}66$. Because $X[1,2] = X[1,1] + X[1,2]$ the value of $X[1,2]$ is not replaced.

- $X[22,2] = \infty$ and at $X[22,1] + X[1,2] = 0{,}41 + 0{,}66 = 1{,}07$. Because $X[2,22] > X[2,1] + X[1,22]$ the value of $X[1,2]$ is replaced to 1,07. It can be interpreted that there is a path from V22 to V2 via V1, with a total weight of 1,07 which is more optimal than the previous path.

In iteration 1, there is a change in the distance between V1 and V22 which indicates that a shorter path has been found through the intermediate nodes considered in this iteration.

The iteration process is carried out 22 times according to the number of nodes involved in the network.

- *Step 4 Determining the Optimal Route*
  The route division is as follows:

✓ Route 1: V1 ─ V22 ─ V21 ─ V20 ─ V19 ─ V18 ─ V15 ─ V14 ─ V13 ─ V12 ─ V1
✓ Total mileage : 0,41 + 1,75 +1 ,25+ 1,75+ 1,12 +0,36 + 0,13 +1,18+1,05+6,69 = 15,69 km
✓ Route 2: V1 ─ V2 ─ V3 ─ V4 ─ V5 ─ V6 ─ V7 ─ V8 ─ V9 ─ V1
✓ Total mileage : 0,66+ 5,88+ 1,41+ 1,10+ 0,52+ 1,64 +0,55+0,46+8,40 = 20,62 km

Thus, the total distance traveled by both routes is 36.31 km and the distribution cost is Rp271,032.00 per month.

➢ *Comparison of Optimization Results*

- *Initial*

Fig 3 Company Initial Route

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- *Saving Matrix*

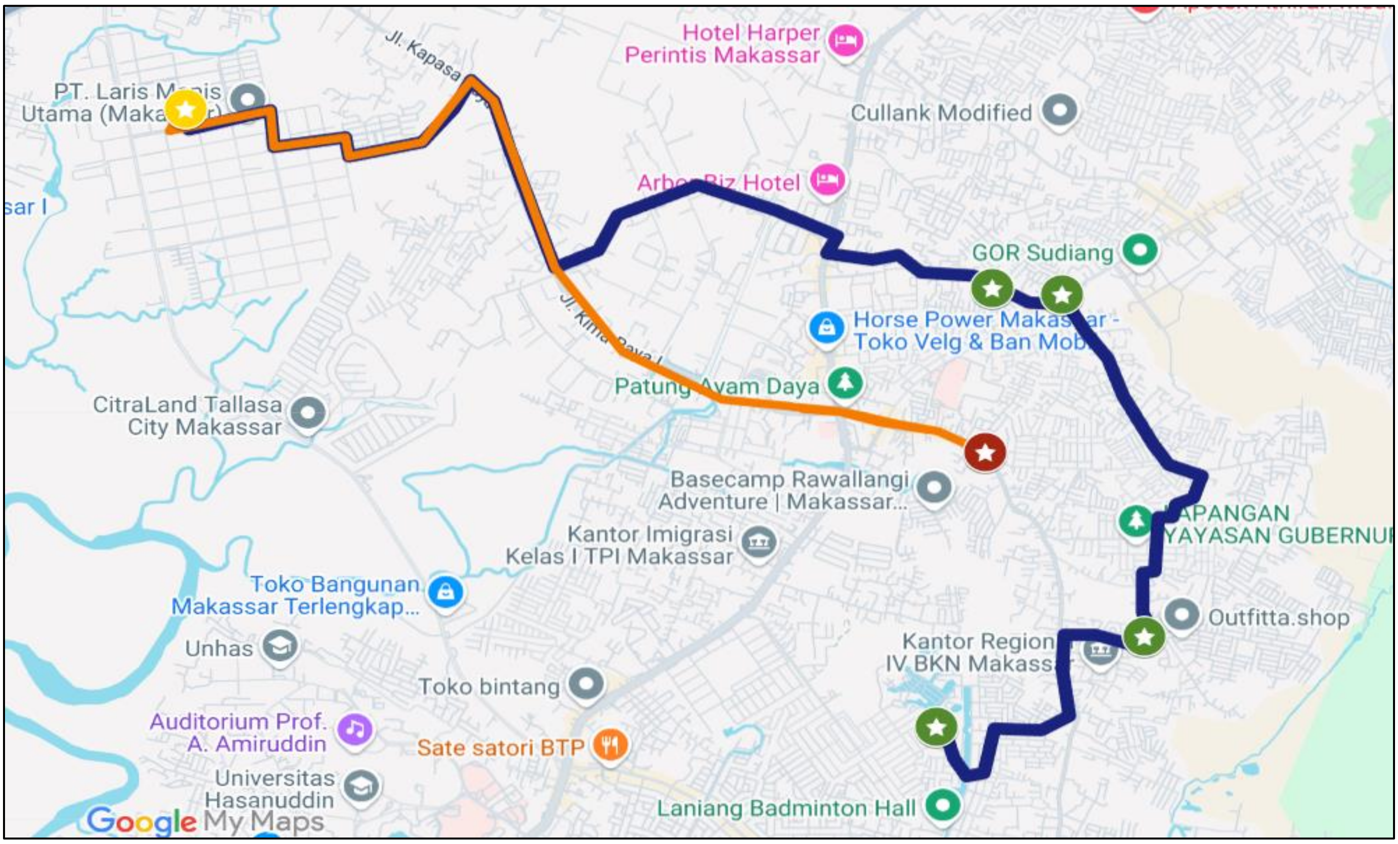

Fig 4 Route Saving Matrix

- *Floyd-Warshall*

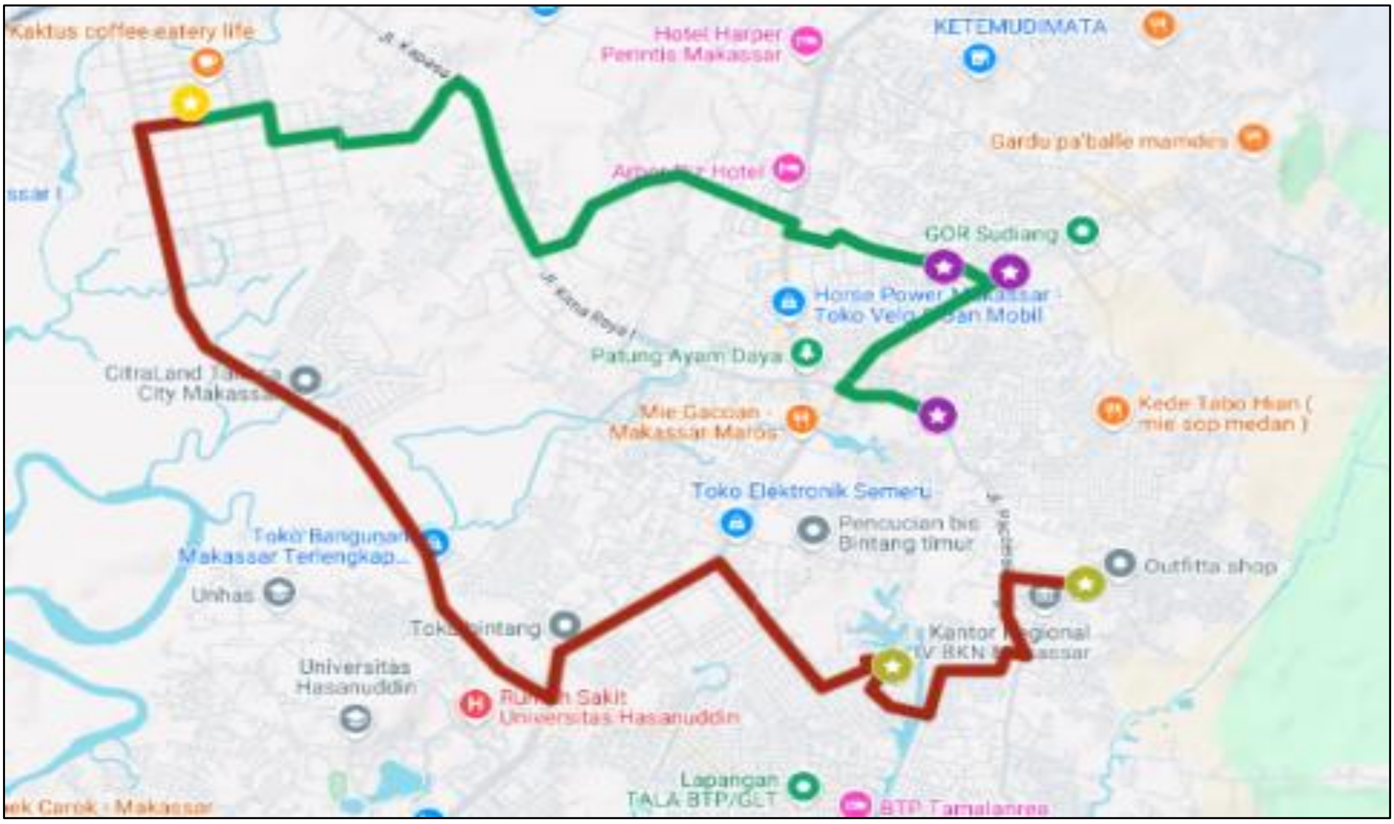

Fig 5 Route Floyd-Warshall

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25aug1112

Based on the optimization results, there is a difference in efficiency between the Saving Matrix method and the Floyd-Warshall method. The following is a comparison table.

Table 8 Comparison of Total Distance and Distribution Cost

Route	Total Distance (Km)	Distribution Cost
Initial	50,4	Rp317.996,00
Saving Matrix	34,3	Rp264.336,00
Floyd-Warshall	36,31	Rp271.032,00

IV. KESIMPULAN

- The initial distribution route implemented by Amanah Logistik Indonesia has a total distance of 50.4 km. The implementation of the Saving Matrix method successfully reduced the total distance to 34.3 km, resulting in savings of 31.94%. Meanwhile, the implementation of the Floyd-Warshall method was able to reduce the total distance to 36.31 km with savings of 27.96%.
- Initial distribution costs were Rp317,996.00. After implementing the Saving Matrix method, distribution costs decreased to Rp264,336.00 per month, resulting in savings of 16.87%. Meanwhile, the implementation of the Floyd-Warshall method was able to reduce distribution costs by Rp271,032.00 with savings of 14.76%.
- Based on these results, the Saving Matrix method provides more optimal results compared to the Floyd-Warshall method both in terms of efficiency of travel distance and distribution costs. The implementation of these two methods generally increases the efficiency of Wahdah Water's distribution, reduces operational costs and speeds up delivery times.

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