Optimal Distribution Route Planning based on Collaboration of Dijkstra and Sweep Algorithm

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I. Introduction

Optimizing the distribution route is one of the essential factors impacting either profit or loss of a company. More than half of company's logistic budget is spent for transportation matter. Hence, applying the efficient way to distributing things is needed for the transportation system in order to gain profit [1].

The best way to create efficiency in transportation route is by computing the smallest distance between existing locations to be visited by vehicle. One way to produce the shortest path is by establishing clusters of target locations, thus node to be visited by vehicles are more specifics and the distance can be reduced as well [2].

In order to finding the shortest route, generally many of the former researches were implemented the method such as Dijkstra Algorithm [5], Bread First Search Algorithm [6], Floyd-Warshall Algorithm [7] or A* Algorithm [8]. Some of the previous researches were successful to implement the combination of those algorithms [9][10][11][12]. For instance, the research that was done by Risald et. al [12] was able to mix Dijkstra Algorithm and Floyd-Warshall Algorithm to find the best route selection of evacuation victims from the traffic accident.

Dijkstra Algorithm was commonly implemented to find the shortest path in transportation system since it considered as one of the best methods compared with all kinds of path planning algorithm[3]. On the other hand, to optimize the route of distribution by clustering nodes based on the polar distance of the main depot, some researchers were using Sweep Algorithm (SWA) as the simplest and more accurate method in heuristics[4].

SWA is known as one variant of the heuristic method which is generating the route according to the polar angle between the stop and the depot. Since it first published in the 1970s, several improvements whether improving it technique or simply it method were done by past researchers [4]. Na et. al [13], were adding some extension to the SWA by combining it with the nearest neighbor method. However, it actually eases the version of original SWA since it removed the inter-route improvements step. They modification were effectual as they gained 5.2% better solution compare with the original version.

According to the important issue of optimizing distribution route, in this research we propose a novel method based on the collaboration of Djikstra Algorithm and SWA. We implement Djikstra Algorithm to creates the best route solution on the cluster generated by SWA. We present information system as the media to implement our theory of the method. The input variable are the locations of the nodes, then that nodes are going to be processed by using SWA method to define the cluster and initial solution of the overall route according to the nodes. After that, Dijkstra Algorithm will optimize the route based on graph weights in each cluster. Then the last step is the best route solution would visualize.

II. Methods

A. Optimization

Optimization is achievements of effective value which by mathematics function it objects to find either the maximum or the minimum value. This optimum value, systematically gained by the process of selecting the best variable [14].

The optimization problem is complex since it value could be defined as length, time, the distance of travel, and et cetera. However, in this research, as focused on distribution route optimization, so a goal of the optimization is reducing the total distance of vehicles that operated by a company [14].

B. Graph

In general theory graph is the pair of denomination between edges and nodes in mathematical form as $G = (V, E)$ which are G as the notation of graph, V as vertices described the dotes, and edges in E notation described as lines that pairing nodes [15].

C. *Sweep Algorithm (SWA)*

Gillet and Miller were presented the original SWA with complicated inter-route improving steps [13], but in this research paper, we consider only its basic version without any inter-route improvement. This is owing to the SWA known as construction algorithm and several studies including use this version.

Algorithm 1 The Sweep Algorithm (SWA)

Step 0. The polar angle between each stop and the depot is computed.
Sort stops in the augmentative way of polar angle (counter-clockwise direction): $s_1, s_2, s_3, \dots s_n$.
Set $k=1$.
Step 1. Insertion order is $s_k, s_{k+1}, s_{k+1}, , \dots s_n, s_1, s_2, \dots, s_{k-1}$.
Step 2. Chose obsolete vehicle.
Step 3. Continue to assign unlined stops to the vehicle according to the insertion order and construct a route while the sum of the demand stops does not meet-exceed the capacity of the vehicle.
Step 4. If an unlined stop is happening, go to step 2.
Else, go to step 5.
Step 5. Optimize each route using 2-opt edge exchange.
Record a solution.
Step 6. If $k<n$, set $k+1$ and go to step 1.
Else, go to step 7.
Step 7. Repeat step 0 – step 6 with the decreasing order of the polar angles (clockwise direction).
Step 8. Return the solution with minimum travel distance.

D. *Djikstra Algorithm*

Dijkstra Algorithm is one of the variants of the greedy algorithm which is a kind of popular algorithm to solve optimization problem [12]. In case of finding the solution, this algorithm works with the greedy principal, by finding the optimum solution on each passing step in order to gain the best solution.

Furthermore, the Dijkstra Algorithm is running with the priority queue which means only the highest priority of nodes will be searching. To decide the most priority node, this algorithm comparing each nodes' weight values on every level. Hereafter gained weight values of nodes is kept to next compare with new nodes that would explore [3].

In general mode, steps of Dijkstra Algorithm work as follows[5].

Algorithm 2 The Dijkstra Algorithm

Step 0. Define v_0 as the point to start and v as the point to finish.
Step 1. Set $v = v - v_0$, with the label of starting point is $(v_0, 0)$; the label of neighboring point is $(v_0, L(v_0, v))$; and the other label is $(v_0 + \infty)$.
Step 2. End the algorithm if $v = \varphi$
Step 3. Apply $v_k \in V$.
if $v_k = v_n$, then end the algorithm.
else, make v_k as the permanent label
then set $v = v - v_k$
Step 4. Analyze the adjacent point v_k
if $L(v_i) > L(v_k) + L(v_k + v_i)$
then set label v_{we} as $[v_k, L(v_i) > L(v_k) + L(v_k + v_i)]$
step 5. Label is given and back to Step 2.

E. *Combination of SWA and Djikstra Algorithm*

In this research we propose a novel method based on the collaboration of Djikstra Algorithm and SWA. We implement Djikstra Algorithm to make the best route solution on the cluster generated by SWA. We present information system as the media to implement our theory of the method. The input variable are the locations of the nodes, then that nodes are going to be processed by using SWA method to define the cluster and initial solution of the overall route according to the nodes. After that, Dijkstra Algorithm will optimize the route based on graph weights in each cluster. Then the last step is the best route solution would visualize.

Algorithm 3 Combination of SWA and Dijktra Algorithm

Step 0-2. (The step is similar with algorithm 1)
Step 3. Choose the next path using Dijkstra algorithm to meet the most minimum cost of distance.
Step 4-8. (repeat the step 4-8 as explain in algorithm 1).

III. RESULT AND DISCUSSION

A. *Case of Study*

Implementing the method of our research, we were using the real case of the premium gasoline distribution route in the Pertamina Depo Malang, East Java, Indonesia. Our subject has the responsibility to provide and deliver premium gasoline to 15 gas stations (customers) existing in the city of Malang (shown in Table I and illustrated in Figure 1).

TABLE I. CUSTOMERS' COORDINATES AND DEMANDS

Nodes	Demand	Longitude	Latitude
1	37 kiloliters	112.602923	-7.931374
2	29 kiloliters	112.627474	-7.937646
3	29 kiloliters	112.619700	-7.995333
4	25 kiloliters	112.614608	-7.983133
5	16 kiloliters	112.627730	-8.016334
6	14 kiloliters	112.637443	-7.980579
7	22 kiloliters	112.626640	-7.986138
8	26 kiloliters	112.624072	-7.961933
9	21 kiloliters	112.613377	-7.957075
10	15 kiloliters	112.657705	-7.985239
11	8 kiloliters	112.627091	-8.031011
12	27 kiloliters	112.645498	-7.978031
13	13 kiloliters	112.642764	-8.037420
14	22 kiloliters	112.603089	-7.964186
15	15 kiloliters	112.600780	-7.898000

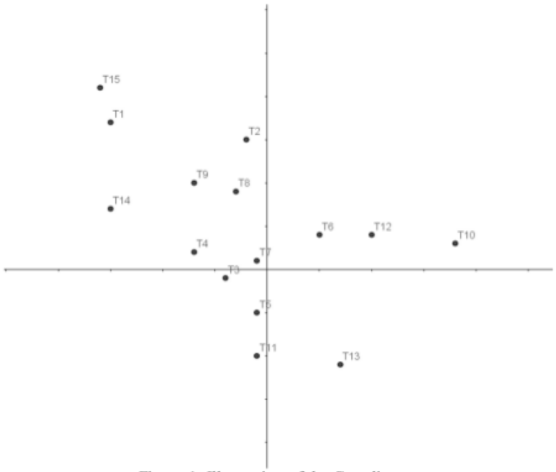

Figure 1. Illustration of the Coordinates

There are 319 kiloliters of average demands from 15 gas stations in the city of Malang were distributed through 2 phases of delivers, which was the first phase using 13 vehicles and the second phase using 2 vehicles (shown in Table II). The total distance travel was 115 kilometers that was 90 km for phase 1 and 24 kilometers for phase 2, while the time travel was 2 hours and a half (according to distances' matrix shown in Table III).

TABLE II. PHASE OF DISTRIBUTIONS

Vehicle	Phase 1	Phase 2	Total of Vehicles	Total of Travel's Distance
Truck 24 kiloliters	13 vehicles	2 vehicles	15 vehicles	115 kilometers

TABLE III. DISTANCES' MATRIX

Nodes	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0		13	10	2	3	4	2	1	5	6	4	6	4	8	6	17
1	13		5	8	6	11	8	8	5	3	11	13	9	15	5	8
2	10	5		8	7	10	6	7	4	4	9	12	6	13	7	7
3	2	8	8		2	5	4	1	5	5	6	5	5	7	5	15
4	3	6	7	2		6	4	2	4	3	5	7	5	9	3	13
5	4	11	10	5	6		4	4	8	8	6	2	5	4	8	18
6	2	8	6	4	4	4		2	4	5	4	9	1	7	5	14
7	1	8	7	1	2	4	2		3	5	4	6	3	8	5	15
8	5	5	4	5	4	8	4	3		2	7	9	5	11	3	11
9	6	3	4	5	3	8	5	5	2		8	10	6	12	2	9
10	4	11	9	6	5	6	4	4	7	8		8	4	6	9	16
11	6	13	12	5	7	2	9	6	9	10	8		8	2	10	20
12	4	9	6	5	5	5	1	3	5	6	4	8		8	6	14
13	8	15	13	7	9	4	7	8	11	12	6	2	8		12	21
14	6	5	7	5	3	8	5	5	3	2	9	10	6	12		12
15	17	8	7	15	13	18	14	15	11	9	16	20	14	21	12	

B. Implementation

According to those locations of the gas stations, we were able to calculate the on polar coordinates (shown in Table II) that we found by using the equations of:

$$r = \sqrt{x^2 + y^2} \qquad (1)$$

$$\theta = \arctan\left(\frac{y}{x}\right) \qquad (2)$$

TABLE II. POLAR COORDINATES

Nodes	Address	*R*	*θ*
1	Jl. Tlogomas	22.67	2.29
2	Jl. Sukarno – Hatta	15.13	1.70
3	Jl. S. Supriyadi	4.12	3.39
4	Jl. R. Langsep	7.28	2.86
5	Jl. Kol. Sugiono Gadang	5.10	4.51
6	Jl. Trunojoyo	6.40	0.67
7	Jl. Yulius Usman Sawahan	1.41	2.36
8	Jl. Bandung	9.49	1.89
9	Jl. Bend. Sutami	12.21	2.18
10	Jl. Ki. Ageng Gribig	18.25	0.17
11	Ds. Lowokdoro	10.50	4.61
12	Jl. Mayjend Wiyono	10.77	0.38
13	Jl. Mayjend Sungkono	13.40	5.28
14	Jl Puncak Tidar	16.55	2.70
15	Jl. Raya Dadap Rejo	26.40	2.22

Because we were already figuring out those polar coordinates, hence we could define clusters of each node by using Euclidian distance (shown in Table III and Depict in Figure 2).

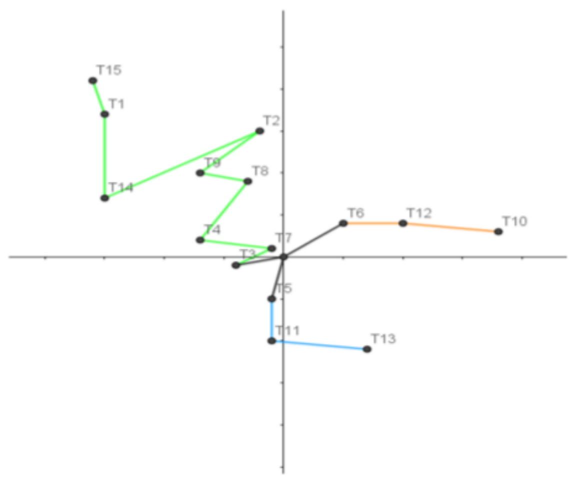

Figure 2. Illustration of the Polar Coordinates on Clustering

TABLE III. CLUSTERING THE POLAR COORDINATES

Nodes	$\theta - r$	$(\theta - r)^2$	$\sqrt{(\theta r)}$	Clusters
1	-20.38	415.3444	20.38	3
2	-13.43	180.3649	13.43	3
3	-0.73	0.5329	0.73	3
4	-4.42	19.5364	4.42	3
5	-0.59	0.3481	0.59	1
6	-5.73	32.8329	5.73	2
7	0.95	0.9025	0.95	3
8	-7.60	57.7600	7.6	3
9	-10.03	100.6009	10.03	3
10	-18.08	326.8864	18.08	2
11	-5.89	34.6921	5.89	1
12	-10.39	107.9521	10.39	2
13	-8.12	65.9344	8.12	1
14	-13.85	191.8225	13.85	3
15	-24.18	584.6724	24.18	3

For the result of our research we define the created clusters as a configuration then the routes of each cluster were processing with applying Dijkstra Algorithm. Hence, we found the best solution for the distribution route as follows.

1st Cluster route is: $n_5 \rightarrow n_{11} \rightarrow n_{13}$

2nd Cluster route is: $n_6 \rightarrow n_{12} \rightarrow n_{10}$

3rd Cluster route is: $n_3 \rightarrow n_7 \rightarrow n_4 \rightarrow n_8 \rightarrow n_9 \rightarrow n_2 \rightarrow n_{14} \rightarrow n_1 \rightarrow n_{15}$

So according to the distances matrix representing the total length between each node, we found that for the first cluster the distance is 16 kilometers, distance for the second cluster is 14 kilometers, and the last cluster 75 kilometers distance of travels. So that the total distance travels for all utilized vehicles is 105 kilometers.

IV. CONCLUSION

Our paper is utilizing the combination of Djikstra Algorithm and SWA to optimize distribution route. the result of this combination method is shown that there are improvements both on reducing the total distance and abbreviating the time travel needs. For the total distance we successfully achieve 9% refinement, then for the time travel, as we are dividing clusters onto clusters which able to make more organized route planning, hence the fastest original total time travel 2 hours and a half is able to subtract become under an hour trip's time.

Therefore, according to the better circumstance that we are acquiring from our research, we believe that implementation of this method in the company that has a delivery activity would gain a better transport management solution that also can save their budget on the logistic operation.

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PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5