Determining Capacitated Vehicle Routing Problem Model with Comparative Analysis of Sweep Algorithm and Heuristic Algorithm in Newspaper Company: A Case Study

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Abstract

The main factors in achieving maximum company profits is the distribution of goods/products. Optimal distribution means that the product is received by the consumer in the right quantity, in good condition, at the time promised and at a low cost. One example in the case of the newspaper industry, there is a problem related to determining vehicle routes that aim to minimize route distances and minimize transportation costs from distribution warehouses to consumers or what is commonly called the Capacitated Vehicle Routing Problem (CVRP). CVRP is related to determining the distribution channel of a product optimally. The purpose of this research is the formation of the Capacitated Vehicle Routing Problem model on the daily distribution route problem of PT. ABC in the Solo Raya area by using a comparison between the sweep algorithm and the heuristic algorithm. The results of the study showed that the best method to solve CVRP problems at PT. ABC is a heuristic algorithm with less distance traveled than the sweep algorithm method.

Keywords

Capacitated Vehicle Routing Problem (CVRP), Distribution Route, Heuristic Algorithm, Newspaper Company, and Sweep Algorithm

1. Introduction

The problems faced by PT. ABC is about the distribution process that is not optimal in determining routes. Therefore, it causes the length of distribution so that the existing agents also take a long time to distribute to customers/consumers. Where the details of the problems that we raise are regarding the newspaper distribution flow system to both agents

and consumers. This is because newspaper distribution is unique because it has *time windows* and the *plan–make–deliver–return process* in the newspaper industry only lasts less than one day or 24 hours. So to expedite and accelerate its distribution, PT. ABC script must group agents in each region and find the best route so that distribution can take place quickly and effectively. So that the route problem in the case of PT. ABC script can be resolved properly.

With the distribution system, companies can pick up and deliver goods from or to customers who are geographically dispersed. In accordance with a predetermined request using a fleet as a means of transportation. So PT ABC grouped agents in a certain area, but needed a good route determination so that the distribution operational time and costs were effective and efficient. Currently the product distribution process is still limited to certain areas starting from the nearest agent but does not yet have a fixed route.

The sweep algorithm consists of two stages, namely clustering agents and establishing routes for each agent that has been clustered using the Nearest Neighbor method. The heuristic method is carried out by forming sub routes using the saving matrix method. Where the objective of this research is to find the most optimal route for the distribution of newspapers in the Solo Raya area by using both methods and determining the best method so that the distribution process of newspapers can run more effectively.

The Capacitated Vehicle Routing Problem (CVRP) is the most basic form of VRP (Layeb and Chikhi, 2014), which can be seen as the formulation of two well-known pre-existing problems namely, the Traveling Salesman Problem and the Bin Packing Problem (Gunawan et al, 2012). *The Capacitated Vehicle Routing Problem* is one of the most common problems of the Vehicle Routing Problem, which is described as a depot center or center, which uses vehicle modes with a certain capacity to serve the requests of a number of agents. Increasing competition between companies, as well as increasing expectations of quality and service from customers, requires not only more operating schedules and accurate planning processes but also cost reductions in the logistics function (Verdonck et al, 2013). Therefore, we need a solution to optimize the preparation of the route problem. The optimal route can be determined using *sweep* algorithms or heuristics. The *sweep* algorithm was first introduced by Gillet & Miller in 1974 where the clustering begins by placing the depot as the center point of the coordinates and surrounded by nodes that are randomly distributed according to geographic location. In solving CVRP problems, the sweep algorithm requires two stages of the process, namely the clustering and route formation stages. The first stage of the sweep algorithm method is the Clustering stage. The *sweep* algorithm is an algorithm with 2 phases, namely the clustering phase and the route creation phase for each cluster (Saraswati et al, 2017. The clustering phase is grouping customers based on the available area and vehicles. The distribution route phase is forming a route by determining one starting point to a point visit. The algorithm heuristic an algorithm to model the quadratic programming problems (Lovarto et al, 2010).

The application of the CVRP model using the Sweep algorithm requires two stages, namely the clustering phase and the route formation phase (Gunawan et al, 2012 and Nono et al, 2020):

a. Stage of grouping (clustering)
   The steps taken at the grouping stage are:
   1. Determine each agent's position in Cartesian coordinates and assign the location of the depot as the center of the coordinates.
   2. Determine all polar coordinates of each agent with the initial depot.
      $r = \sqrt{x^2 + y^2}$
      $\theta = \arctan\frac{x}{y}$
      Information:
      $\mathrm{r} = \text{polar coordinate}$
      $\theta = \text{polar coordinate}$
      $\mathrm{x} = \text{cartesius coordinate}$
      $\mathrm{y} = \text{cartesius coordinate}$
   3. Forming a grouping (clustering) starting from the agent that has the smallest to the largest polar angle by considering the capacity of the vehicle.
   4. Ensure all agents involved have been grouped in this cluster.
   5. Grouping is stopped if there is one cluster that will exceed the maximum vehicle capacity. If this happens, then a new cluster is created as in the previous step.
b. Distribution route formation stage
   The stage of establishing distribution routes. The steps are as follows:

1. Initiation step
   - Determine one point as the starting point of the trip, namely from the company depot
   - Determine the set of points (C) to be visited by the vehicle.
   - Determine the order of temporary distribution routes.
   - Choose the next point that the vehicle visits.
2. If n_1 is a point in the last sequence of route R then the next point n_2 has the minimum distance from n_1, where n_2 is a member of C . If many optimal choices mean that there is more than one point with the same distance from the last point in route R and that distance is the minimum distance, choose randomly.
3. Adds the selected point to the next route sequence. Adds n_1 points to the final sequence of the temporary route and removes the selected point from the list of unvisited points.
4. If all points have been passed, then the route is closed by adding an initiation point or starting point of the journey at the end of the route.

There are two types of heuristic functions that can be used, namely:

a. H1 = number of squares whose position is correct.
b. H2 = distance between initial state and goal state.

The way to calculate it is by adding up the absolute value of the difference between the column and row in the initial state and the goal state. The total value of h1 and h2 is a maximum of 9, namely the maximum H1 if the tile position is in accordance with the goal State is 9 and H2 is 0 (zero). The position heuristic is the value of the match between initial State and goal State if:

a. Number of tiles occupying the correct position: higher count is expected (better).
b. Number of tiles occupying the wrong position: the smaller the expected number (the better).

2. Methods

The stages of the method used to achieve the research objectives regarding CVRP are data collection, data processing, and the process of applying the method. In this study, the data used include the number of agents, the location of agents, the number of fleets, the maximum capacity of the fleet for delivery, and the demand for newspapers for the Surakarta City area. However, considering that the maximum capacity of the fleet to transport newspapers is assumed to be 2000 newspapers. Processing the data obtained using the help of the google maps application to find out the distance from each agent and the required travel time according to what is listed on google maps. Then the data that has been collected will be processed and used to perform calculations using the sweep algorithm and heuristic methods. So from the results that have been obtained then an analysis of the two methods was carried out.

2.1 Data collection

Data collection methods used were observation in the company of an accurate source realistically according to the situation that existed at the company. In this study, the data used include data on the number newsagent, new agent location, distance matrix of each agent to the depot, and time service in every agency. In this study focuses only on the distribution of the newsagent. This study uses the assumption that 3 fleet with a maximum capacity of 2000 newspapers. Here is the data that will be used to support this research.

2.2 Data processing

Processing the data obtained using the help of the google maps application to find out the required travel time and the locations between agents. However, with the assumption that when delivering and picking up daily newspapers without experiencing any problems with smooth traffic.

2.3 Application of the Method

The steps of applying the method to be carried out for solving existing problems are as follows.

1. Identify the problem formula
2. Create a conceptual model
3. Input/output data processing
4. Performing simulations using the sweep algorithm and heuristic algorithm methods
5. Determine the alternative criteria that have been obtained
6. Select and analyze the output of alternative solutions to be used
7. Making decisions

The application of the method comes from research from (Saraswati et al, 2017) and (Sentika, 2018).

3. Data Collection

Based on the journal Jodinesa (2019), the data used for processing are agent data, agent locations, and demand from each agent. The following is a table 1 which shows the agent data, agent locations, and demand per agent.

Table 1. Agent Data, Agent Location, and Demand per Agent

Agent	Demand
A1	290
A2	294
A3	550
A4	623
A5	192
A6	1267
A7	115
A8	115
A9	580
B1	110
B2	92
B3	105
C1	143
C2	90
C3	105

The following is table 2 which shows the coordinate data for each agent that will be used for data processing based on the journal from Jodinesa (2019).

Table 2. Agent Location Coordinate Data

Agent	Location Coordinates	
	X	Y
A1	-7,545586	110,77916
A2	-7,545586	110,77916
A3	-7,550793	110,81788
A4	-7,553314	110,820476
A5	-7,553469	110,820597
A6	-7,568512	110,823682
A7	-7,567927	110,81713
A8	-7,572134	110,823997
A9	-7,573876	110,818691
B1	-7,547211	110,76459
B2	7,5376275	110,837241
B3	-7,5540565	110,827214
C1	-7,5636606	110,798225
C2	-7,5515164	110,81642
C3	-7,5515164	110,81642

4. Results and Discussion

This section contains the results of a discussion on the CVRP research at PT ABC. Where there are numerical results and graphical results.

4.1 Numerical Results

Based on the data that has been processed, the numerical results are obtained in tabular form. This numerical result is obtained based on the sweep algorithm and heuristic methods. The following is numerical data that will be presented for further analysis.

The results obtained from the data processing of the coordinates of ABC newsagent is a table containing the polar coordinates of the agent (θ). The following are the polar coordinates of ABC newsagent in table 3.

Table 3. Data Polar coordinates (θ)

Agent	Location Coordinates		X/Y	(θ)
	X	Y		
A1	-7,545586	110,77916	-0,068113768	-3,896612776
A2	-7,545586	110,77916	-0,068113768	-3,896612776
A3	-7,550793	110,81788	-0,068136956	-3,897935208
A4	-7,553314	110,820476	-0,068158108	-3,899141547
A5	-7,553469	110,820597	-0,068159432	-3,89921707
A6	-7,568512	110,823682	-0,068293273	-3,906850051
A7	-7,567927	110,81713	-0,068292032	-3,906779268
A8	-7,572134	110,823997	-0,068325762	-3,908702851
A9	-7,573876	110,818691	-0,068344752	-3,909785886
B1	-7,547211	110,76459	-0,068137398	-3,897960447
B2	7,5376275	110,837241	-0,068006271	-3,890482079
B3	-7,5540565	110,827214	-0,068160664	-3,899287306
C1	-7,5636606	110,798225	-0,068265178	-3,905247806
C2	-7,5515164	110,81642	-0,068144381	-3,898358698
C3	-7,5515164	110,81642	-0,068144381	-3,898358698

The following is an example calculation for the values of x/y and theta on agent A1:

$$\frac{x}{y} = \frac{\text{location coordinates X}}{\text{location coordinates Y}}$$

$$\frac{x}{y} = \frac{-7{,}545586}{110{,}77916} = -0{,}068113768$$

$$\theta = \arctan\frac{x}{y}$$

$$\theta = \arctan\frac{-7{,}545586}{110{,}77916} = -3{,}896612776$$

Perform *clustering* / grouping by sorting the polar coordinates from the smallest to the largest. The following is a table 4 describes the results of the clustering that has been done.

Table 4. Clustering Sweep Algorithm Method

Cluster	Agent	Location Coordinates		X/Y	(θ)	Demand	Total Demand
		X	Y				
I	A9	-7,573876	110,818691	-0,068344752	-3,909785886	580	1962
	A8	-7,572134	110,823997	-0,068325762	-3,908702851	115	
	A6	-7,568512	110,823682	-0,068293273	-3,906850051	1267	
II	A7	-7,567927	110,81713	-0,068292032	-3,906779268	115	1483
	C1	-7,5636606	110,798225	-0,068265178	-3,905247806	143	
	B3	-7,5540565	110,827214	-0,068160664	-3,899287306	105	
	A5	-7,553469	110,820597	-0,068159432	-3,89921707	192	
	A4	-7,553314	110,820476	-0,068158108	-3,899141547	623	

	C2	-7,5515164	110,81642	-0,068144381	-3,898358698	90	
	C3	-7,5515164	110,81642	-0,068144381	-3,898358698	105	
	B1	-7,547211	110,76459	-0,068137398	-3,897960447	110	
III	A3	-7,550793	110,81788	-0,068136956	-3,897935208	550	1226
	A1	-7,545586	110,77916	-0,068113768	-3,896612776	290	
	A2	-7,545586	110,77916	-0,068113768	-3,896612776	294	
	B2	7,5376275	110,837241	-0,068006271	-3,890482079	92	

After clustering, the distance and time from each cluster can be searched. The route obtained is divided into 3, using the help of the google map application, the following is the result of the distance traveled and travel time in each cluster. The following is the result of the distribution route of ABC newspaper along with the distance and travel time in each cluster using the google maps application which was obtained using the sweep algorithm method as shown in table 5.

Table 5. Distribution Route of Newspaper with *Sweep.* Algorithm Method

Route	Distance (km)	Time (minute)
Depot – A9 – A8 – A6	7,8	19
Depot – A7 – C1 – B3 – A5 – A4 – C2 – C3 – B1	22	49
Depot – A3 – A1 – A2 – B2	8,8	23

From the table above, the distance and time obtained came from the help of the google maps application so that it was found that the route for cluster 1 was from the depot to agents A9, A8, A6 the distance traveled was 7.8 km, while the travel time was 19 minutes. The route taken by cluster 2 is starting from the depot to agents A7, C1, B3, A5, A4, C2, C3, B1 then the distance covered is 22 km, and the time taken is 49 minutes. Then the route taken for cluster 3 is starting from the depot to agents A3, A1, A2, B2 and the distance covered is 8.8 km while the time taken is 23 minutes.

4.2 Graphical Results

This section contains the *graphical results* (image results) obtained from the help of the google maps application. The following is a figure 1 of the cluster r 1 distribution route for the sweep algorithm method.

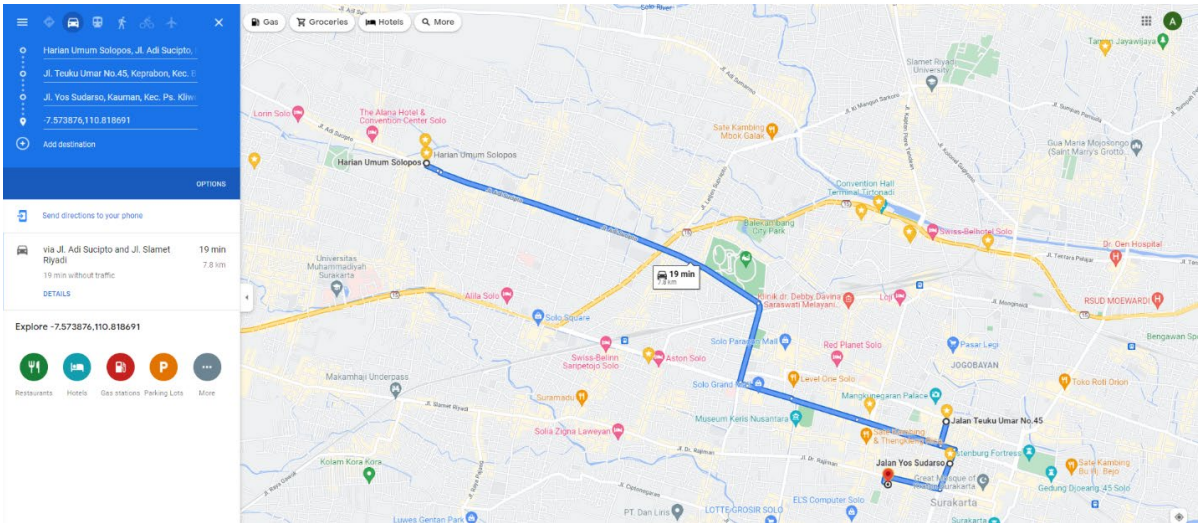

Figure 1. Cluster I Distribution Route Sweep Algorithm Method

The following is a figure 2 of the distribution route for ABC newspaper for cluster 2 that must be taken using the *sweep* algorithm method.

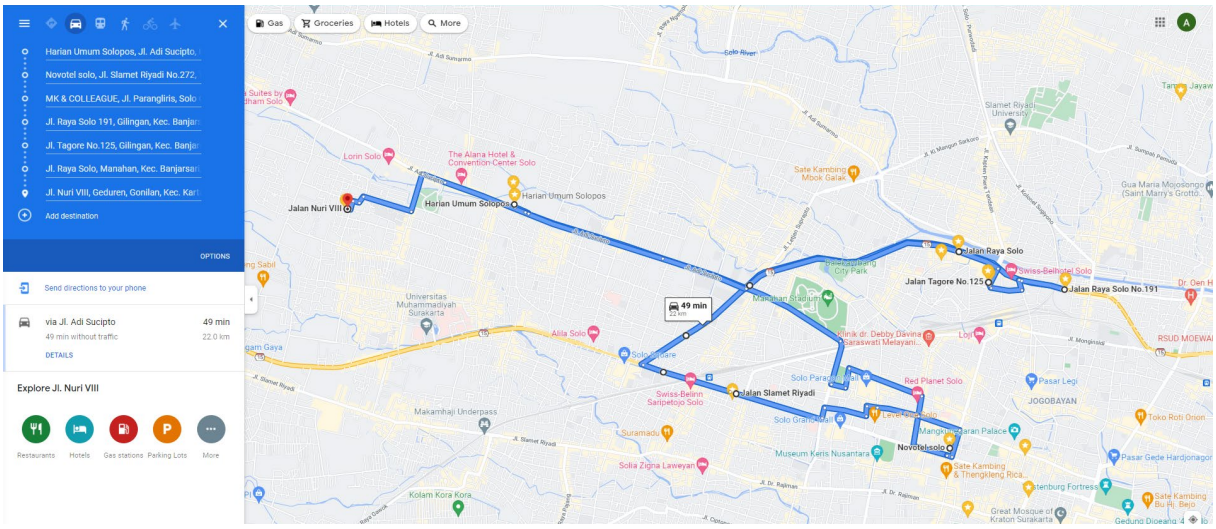

Figure 2. Cluster II Distribution Route with Sweep Algorithm Method

The following is a figure 3 of the distribution route for ABC newspaper for cluster 3 that must be taken using the sweep algorithm method.

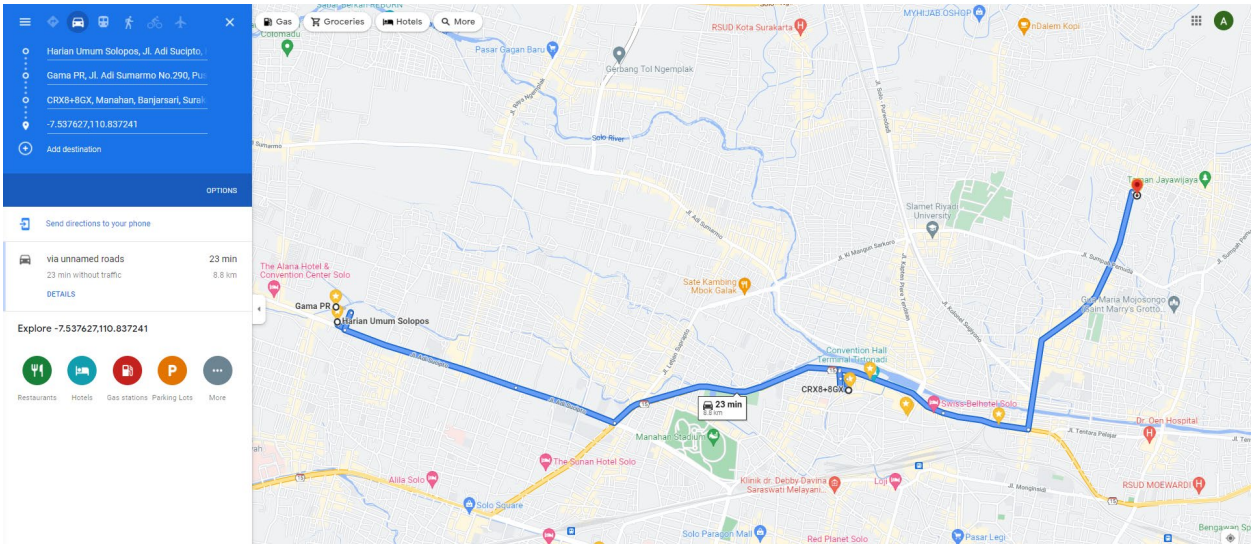

Figure 3. Cluster III Distribution Route *Sweep* Algorithm Method

By using the heuristic algorithm method, the results of the mapping and the results of the index point of route 1 obtained are as shown in figure 4.

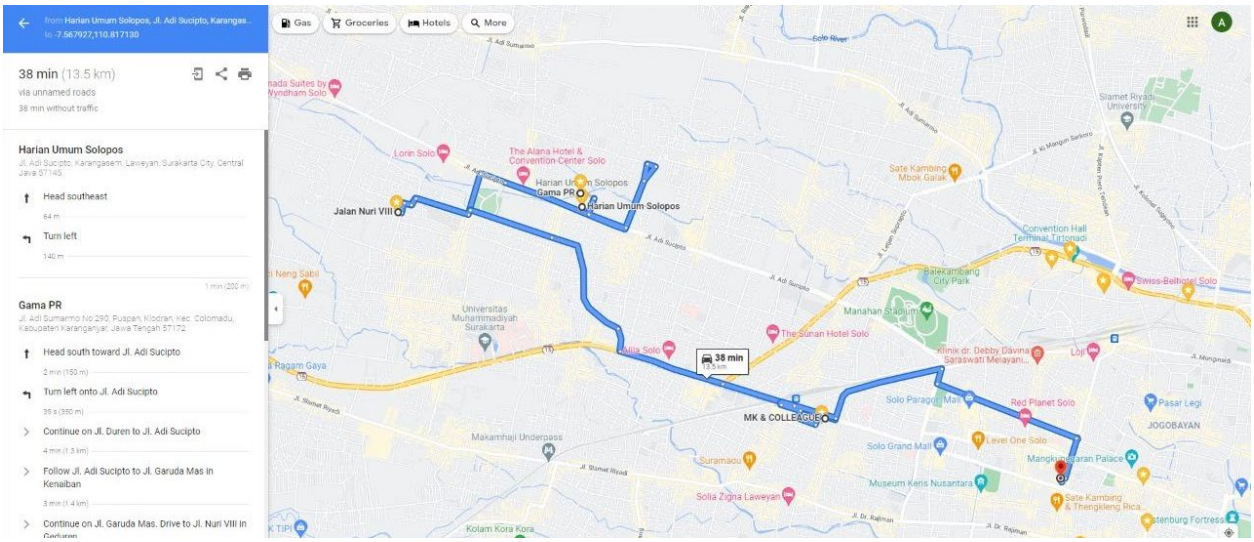

Figure 4. Distribution Route I Heuristic Algorithm Method

By using the heuristic algorithm method, the results of the mapping and the results of the route 2 index points obtained are as shown figure 5.

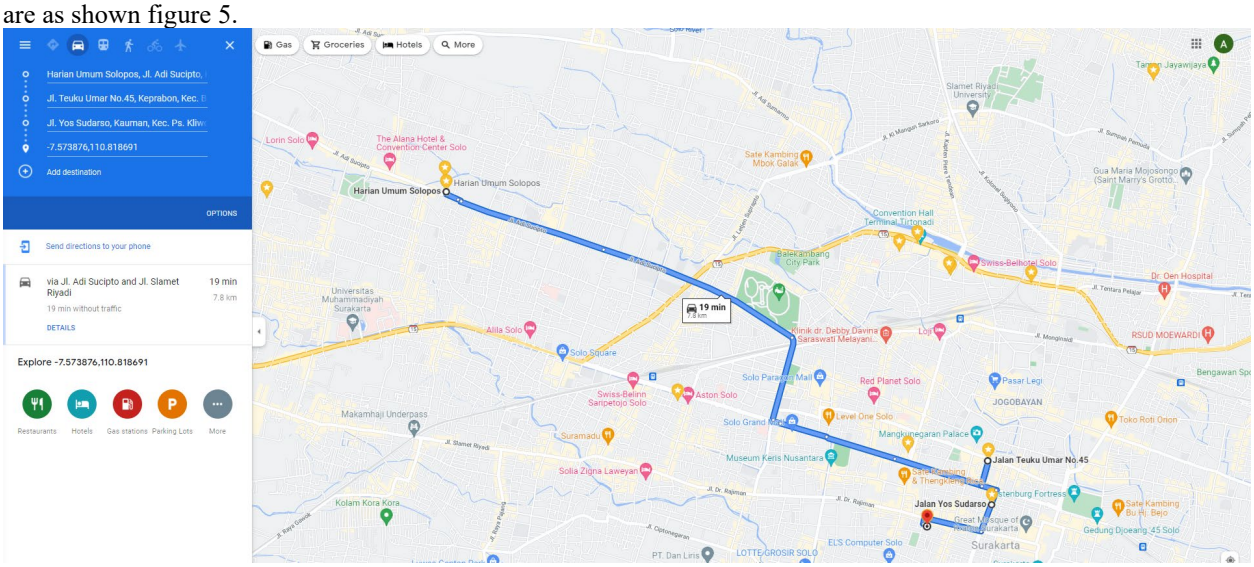

Figure 5. Distribution Route II Heuristic Algorithm Method

By using the heuristic algorithm method, the mapping results and the results of the route 3 index points obtained are as shown figure 6.

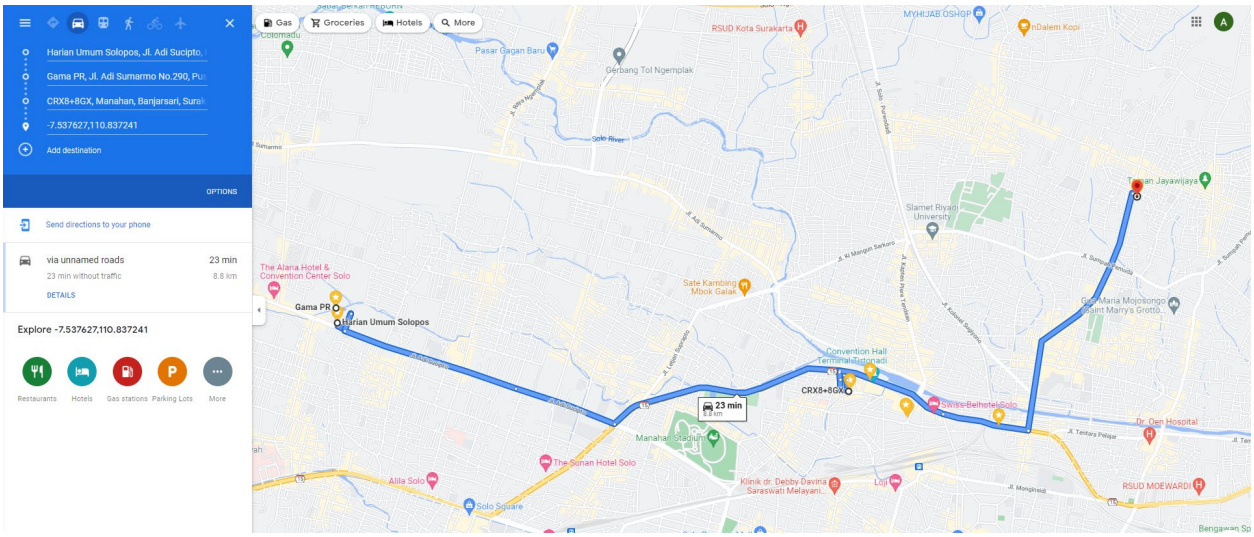

Figure 6. Distribution Route III Heuristic Algorithm Method

After that determine the index point based on the data from the mapping that has been done. Where this index point represents 200m for each point. The following is the index point of route 1 using the heuristic method as shown figure 7.

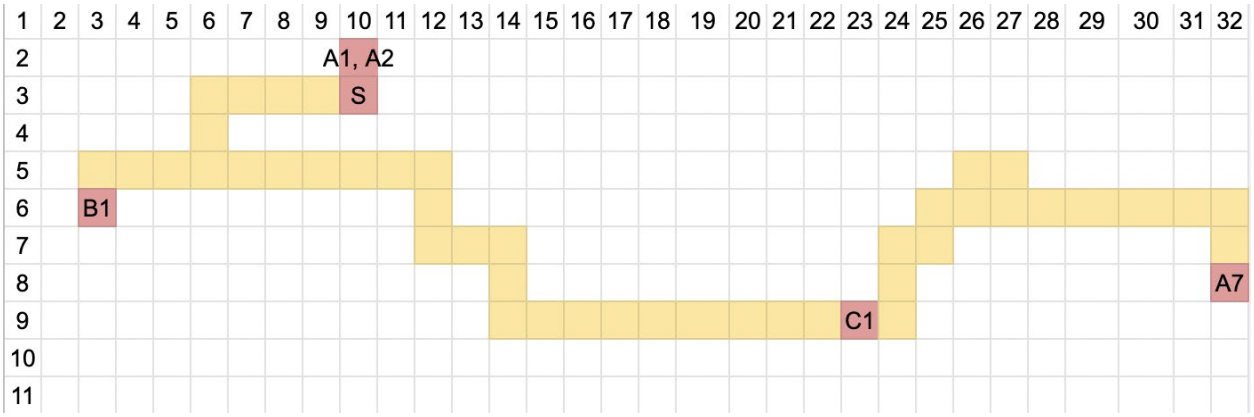

Figure 7. Distribution Route Index Point I Heuristic Algorithm Method

The following is a mapping of route 2 index points using the heuristic algorithm method as shown figure 8.

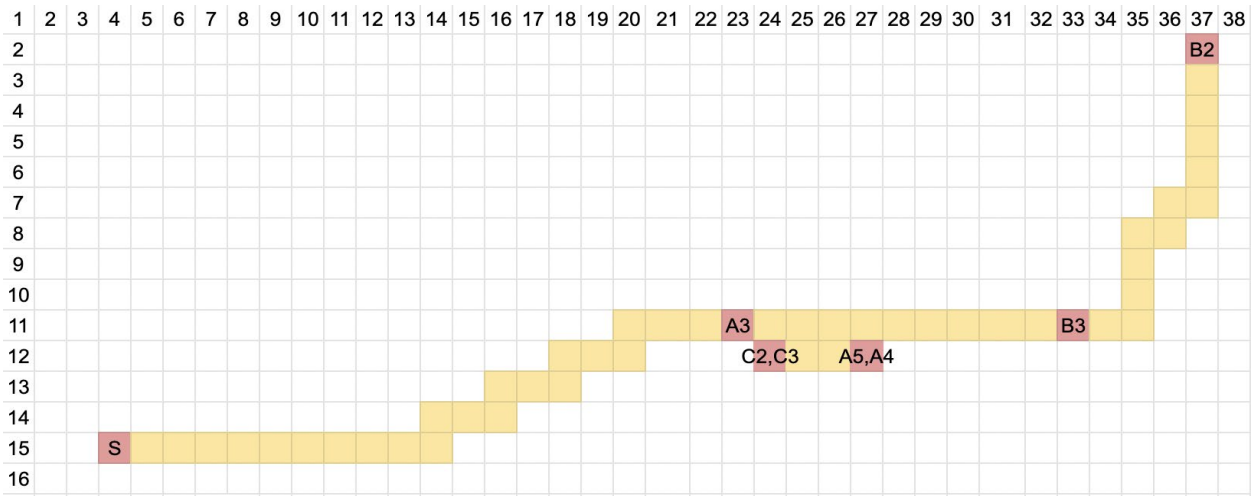

Figure 8. Point Distribution Route Index II Heuristic Algorithm Method

The following is a mapping of route 3 index points using the heuristic algorithm method as shown figure 9.

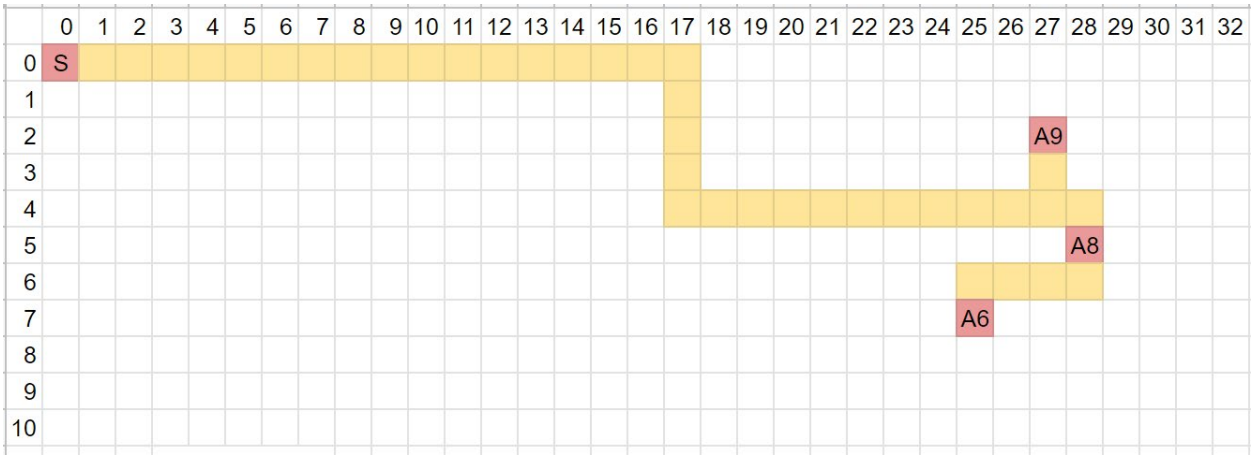

Figure 9. Point Distribution Route Index III Heuristic Algorithm Method

Based on the calculations that have been done
The sweep method produces 3 clusters, namely
Cluster 1: A9, A8, A6
Cluster 2: A7, C1, B3, A5, A4, C2, C3, B1
Cluster 3: A3, A1, A2, B2

The Heuristic method produces 3 clusters, namely
Cluster 1: A1, A2, B1, C1, A7
Cluster 2: A6, A8, A9
Cluster 3: A3, A5, A4, C2, C3, B3, B2,

The following is a comparison table for the total distance of the sweep algorithm method and the heuristic algorithm as shown in table 6.

Table 6. Comparison of the Distance between Sweep Algorithm and Heuristic Algorithm

Ratio	Sweep Algorithm	Heuristic Algorithm
Cluster 1	7.8	13.5
Cluster 2	22	7.8
Cluster 3	8.6	10.4
Total distance (km)	38.4	31.7

5. Conclusion

PT. ABC script experienced distribution problems which could result in delays in delivery. This is because newspaper distribution is unique because it has time windows and the plan–make–deliver–return process in the newspaper industry only lasts less than one day or 24 hours. Research on distribution is carried out to solve distribution problems. The approach of the Capacitated Vehicle Routing Problem model on the problem of the daily distribution route of PT. ABC in the Solo Raya area is solved by using a comparison between the sweep algorithm and the heuristic algorithm. Based on the results of research that has been done in the Capacitated Vehicle Routing Problem by using a sweep algorithm calculation and heuristic algorithm. And with the support of data collection obtained from various sources, including by using the Google Maps application in determining the distribution path that will be chosen by the researcher. Then the optimal route chosen is the route based on the heuristic method, namely by producing 3 clusters of distribution lines with a total distance of 31.7 km.

Suggestions for further research are to try to calculate the estimated travel time or travel length by considering several elements, including the level of congestion that may occur or the number of traffic lights along the way which may also affect the length/time of the trip.

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