Determining Newspaper Distribution Routes using Cheapest Insertion Heuristic Algorithm with Sweep Clustering: A Case Study

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Abstract

PT Aksara Solopos is a newspaper publishing company with daily distribution. One of the problems that often occur in the Newspaper Industry is the delay in the delivery of newspapers to customers. In this study, the solution to the Capacitated Vehicle Routing Problem was solved using the Cheapest Insertion Heuristic algorithm and the sweep algorithm on the daily distribution. The sweep algorithm is a two-stage algorithm, the first stage consists of customer clustering in which the initial clustering is done by connecting the points in one cluster based on the maximum capacity of the vehicle, and the second stage is forming routes for each cluster. The Cheapest Insertion Heuristic Algorithm is an Insertion algorithm in which each additional auxiliary point to be inserted into the subtour has the minimum insertion weight. Data collection uses historical data aka secondary data, does not make direct observations due to the COVID-19 pandemic. The research only focuses on the distribution of newsagents in the Kartasura-Klaten-Sragen area and does not consider the rate of return. The addition of data that assumes the number of agents is 2, geographic coordinate data, namely latitude and longitude from the agent's location using Google Maps, and distance matrix data between agents and PT Aksara Solopos. Based on the distance traveled for each route that has been obtained, the three travel times is less than 5 hours of newspaper delivery. So that it is in accordance with the company's time windows policy.

Keywords
Best routing, Sweep clustering, Cheapest Insertion Heuristic, Capacitated Vehicle Routing Problem.

1. Introduction

Distribution plays an important role as a connector between the company and the customer (Chandra and Setiawan 2018). Rapid market growth demands an acceleration of the distribution process by shortening the distance between the point of production and the point of consumption (Nong and HA 2021). VRP is an optimization problem aiming to determine a route with minimum total cost (Boonkleaw et al. 2010). Newspaper product distribution is different from another products distribution. The business process of the newspaper industry has a special characteristics and is more prominent than other business process especially in the distribution process (Saputra et al. 2017). This case happens because newspaper distribution has a time limit or time windows in its diffusion (Kumar et al 2012; Riskadayanti et al 2019). The solution of the time windows problem is needed if the distribution process has a time problem with a limited number of fleet, it needs distribution cost savings and there is a relative interest among customers (Figliozzi 2010).

PT. Aksara Solopos is a daily newspaper publishing company located in Griya Solopos Jl. Adisucipto 190 Surakarta, Central Java. Globalization and the free trade era have abolished territorial boundaries in the trading system which makes competition within the business world more intense. Furthermore, the existence of new technology, the internet, and digitalization, becomes both challenge and an opportunities for the print media industry in Indonesia (Prihanto 2018). Information access convenience provided by media leading the increase of competition in the business world. An example of the media is the newspaper. The newspaper industry is one of industries that must finish its product with a limit time cycle and rapid movement. News editorial team is required to package the news with short enough time to proceed to the editor and newspaper printing. One of problems that often happen is inappropriate route selection in Newspaper Industry causing a delay in distributing the newspaper to the customers and making the news not up to date. Besides, it also causes wasting time or waste of fuel leading to high operating costs and decreasing popularity due to delays in delivering information to the customers.

Supply chain management is needed in its process which is started from process of production, delivery, diffusion, and product marketing until it reaches the customers. The production process is started at 22.00 up to 02.30. It means that the news search and compilation process is conducted before the production process is carried out. It is because product delivery is carried out at 03.00 until 08.00 using limited transportation (Saraswati, et al. 2017). Therefore, it needs solution for Capacitated Vehicle Routing Problem, which is a problem in determining distribution route to some depots/agents with the start and endpoints of the distribution are the same. In the previous research discussed by Saraswati et al.(2017) stated that the solution which uses sweep algorithm in determining distribution route with results obtained from two routes is in accordance to the cluster with a total time of 5 hours 55 minutes, and it is also in accordance with the time windows policy applied daily by Solopos.

In this research, problem solving for Capacitated Vehicle Routing Problem is solved by using Cheapest Insertion Heuristic algorithm and sweep algorithm in the daily distribution of Solopos, and then it is compared to find suitable method to determine optimal distribution route.

1.1 Objectives

The objective of this research is to solve VRP problem using Cheapest Insertion Heuristic algorithm and sweep algorithm to determine optimal distribution route.

2. Literature Review

Vehicle Routing Problem (VRP)

Vehicle Routing Problem (VRP) is a problem in designing a route with minimum cost. It comes and ends in certain depot by using a number of vehicles with homogeneous load capacity to serve a customer. Every customer will be visited by newspaper transport vehicle once a day.

The purpose of VRP is to determine a route with minimum total distance, where every route starts and ends in a depot, and each customer is supplied once in one condition that the total demand in one route does not exceed vehicle capacity (Sarker and Newton 2007).

VRP, simply, can be described as follow:

a. The vehicles will be departed from depot to go to all customers place and they must be come back to initial depot.
b. Each customer is only allowed to be visited once by one vehicle.

c. Each departed vehicle must bring goods and the amounts of the goods are not more than or at same amount with capacity of the used vehicle.
d. Solve the problem to determine a route set to distribute the goods from depot to customers' location with minimum cost.

Capacitated Vehicle Routing Problem

Research conducted by Toth and Vigo (2002) consider the Capacitated Vehicle Routing Problem (CVRP) by considering the basic static and deterministic versions. CVRP is a category of vehicle routing problems characterized by vehicles with limited capacity (Feld et al. 2019). In the case of CVRP, it has a variable cost objective, namely the minimal route. CVRP is optimization to find a route with number of vehicles with certain capacity (homogeneous) which provides number of customer requests, and its request quantity has been discovered before distribution process. The vehicles are departed from depot to deliver the goods and then gone back to initial depot. The distance between two locations is symmetrical, which means that the course of location A to B is equal to the course of location B to A.

Sweep Algorithm

Sweep Algorithm is part of heuristic algorithm aiming to minimize the vehicles route with handled using agglomeration or grouping. Sweep Algorithm is a two-steps algorithm. First step is consisted of customers clustering which the first clustering is conducted by connecting the points in one cluster based on maximum capacity of vehicles. Then, the second step is forming a route to each cluster (Nurcahyo et al. 2002).

Cheapest Insertion Heuristic (CIH) Algorithm

Cheapest Insertion Heuristic Algorithm is an Insertion Algorithm which at each additional auxiliary point that will be inserted into the sub tour has the minimum insertion weight. According to Kusrini and Istiyanto (2007) the order of the CIH algorithm is:

a. The search starts with the first city linked to the last city.
b. Created a subtour link between the 2 cities. What is meant by subtour is a journey from the first city and ends in the first city, for example (1,3) →(3,2) →(2,1) as inthe figure 1

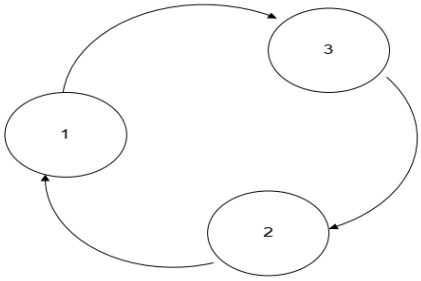

Figure 1. Subtour

c. Replace one of the direction of the relationship (arc) of the two cities with a combination of two arcs, namely arc (i,j) with arc (i,k) and arc (k,j), with k taken from cities that have not entered the subtour and with the smallest additional distance. The distance is obtained from: $c_{ik} + c_{kj} - c_{ij}$
c_{ik} is the distance from city i to city k,
c_{kj} is the distance from city k to city j and
c_{ij} is the distance from city i to city j
d. Repeat step 3 until the entire city is included in the subtour.

Haversine *Formula*

Haversine theorem is a method to find out a distance between two points by considering that the earth is not a flat area yet it is an area having degree of curvature.This theory uses a formula with an equation based on the shape of the earth by eliminating the ellipsoidal factor (Dauni et al, 2019). Haversine theorem is used to count the distance between 2 points based on the straight line length, and between 2 points on the latitude and longitude. The formula of haversine is as follow:

$$a = sin^2\left(\frac{\emptyset_2 - \emptyset_1}{2}\right) + cos\ cos(\emptyset_1)\ cos\ cos(\emptyset_2) sin^2\left(\frac{\lambda_2 - \lambda_1}{2}\right) \quad (1)$$

$$c = 2.atan\left(\sqrt{a}, \sqrt{1-a}\right) \quad (2)$$

$$d = R.c \quad (3)$$

$$d = 2r\left(\sqrt{sin^2\left(\frac{\emptyset_2-\emptyset_1}{2}\right) + cos\ cos(\emptyset_1)\ cos\ cos(\emptyset_2) sin^2\left(\frac{\lambda_2-\lambda_1}{2}\right)}\right) \quad (4)$$

In which, ϕ is latitude, λ is longitude, and R is earth radius.

3. Methods

The research method stage used in this research is data collection stage which is followed by data processing, method application stage, and the final stage is implementation of *cheapest insertion heuristic* (CIH) along with *sweep clustering* algorithm.

Data Collection

Data collection method used in this research is observation which is conducted by using data of the research done by Saraswati et al (2017), or it can be considered as secondary data. The researcher is unable to conduct direct observation due to COVID-19. In this research, previous journal data included amount of vehicle, delivery vehicle's capacity, amount of Solopos newspaper agent, and location of agent. Furthermore, this research only focused on the distribution of newspaper agent within area of Kartasura-Klaten-Sragen without considering newspaper daily return level. Then, demand data addition is assumed that the number of agents increased by 2 agents. It happened because Sragen area does not have Solopos agent yet. Geographic coordinate data is included latitude and longitude of agents location on Google Maps and distance matrix data between agents and PT Aksara Solopos.

Data Processing

Data processing used *Euclidean distance* to process distance matrix data between factory and agents. Meanwhile, as for programming, the researcher used MATLAB as a media to determine the route using *cheapest insertion heuristic* algorithm and Google Spreadsheet to carry out *sweep clustering.*

Method Application

The next is application of analysis of *cheapest insertion heuristic* algorithm along with *sweep clustering.*
In the sweep clustering, a data is selected then it is generated into some clusters using sweep clustering. The process of the sweep cluster is as follow:

1. Represent the data of factory and agent location in the polar coordinate with depot as center of coordinate.
2. Make radial line and determine its direction of rotation.
3. Enlarge the radial angle of the line to cover the first customer
4. Enlarge the radial angle of the line until the covered customers have total demand less than or equal to the vehicle capacity (a cluster is formed).
5. Repeat steps 3 and 4 to form multiple clusters that include all customers.

Each cluster then finds minimum distance route among agents using *cheapest insertion heuristic* algorithm. The processes of *cheapest insertion heuristic* algorithm are as follow:

1. One cluster makes initial sub tour from depot to one customer, then it goes back to the factory.
2. Calculate initial sub tour weight, and select the smallest weight.
3. If, in one cluster, there is agent which is not form sub tour yet, it will be inserted in sub tour which is selected before.
4. Calculate sub tour weight which has been inserted, select the smallest weight.
5. Repeat steps 3 and 4 there are no customers in one cluster that have not yet formed a sub tour.
6. Generates route on the sub tour that has been searched.
7. Repeat steps 1 to 6 to next clusters until each cluster has shortest route.

The flow chart of this research can be seen in Figure 2.

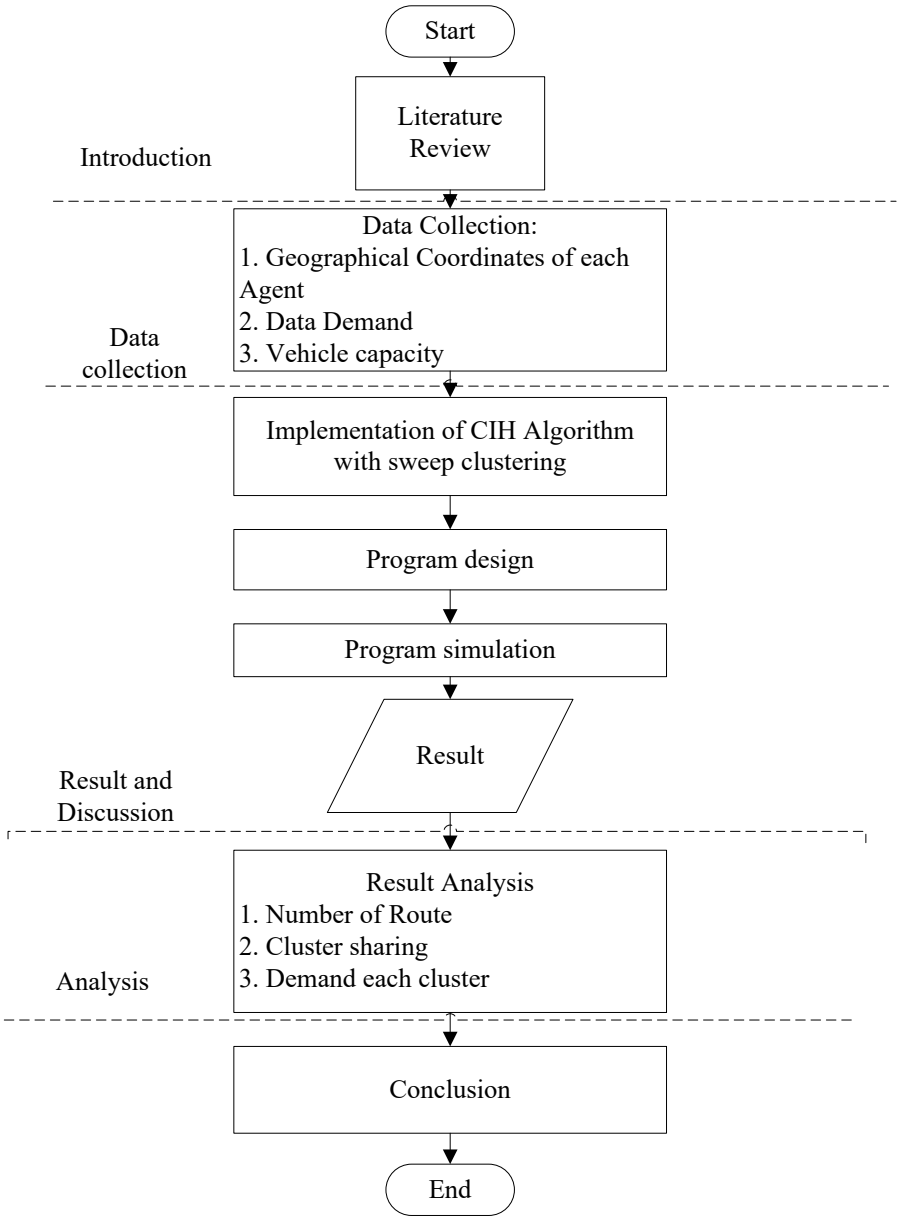

Figure 2. Flowchart of the research

4. Data Collection

This research used data of Solopos daily distribution data of February 2017 assuming an increase in the number of agents from 9 agents to 11 agents in 2021 in Kartasura-Klaten-Sragen area which is displayed in Table 1. The addition of agent in Sragen is because there is no Solopos agent yet in Sragen area. This area was selected because it has the lowest percentage of Solopos daily sales value for Solo Raya area, it was about 40%. The distribution process of Solopos daily newspaper in Kartasura-Klaten-Sragen area uses 3 vehicles which each vehicle has capacity around 3000 copies. This vehicle is used as distribution tool of Solopos daily newspaper to to the 13 agents owned. Daily distribution of Solopos daily newspaper is started from 03.00 am and ended at 08.00 am, with service time duration 1 minutes for 50 copies.

Table 1. Data *Demand*

Agent	*Demand*
A1	189
A2	270
A3	830
A4	560
A5	700
A6	540
A7	204
A8	995
A9	405
A10	858
A11	436

ate data of latitude and longitude of each agent is displayed in the Table 2. The coordinate is processed with Google Maps Application by entering address of the agent which has been got from the company. Then, the distance matrix between agents and factories is shown in Table 3. Meanwhile, the factory and agent diffusion data can be seen on the Figure 3.

Table 2. Geographical Coordinates of Factory and Each Agent

Agent	Address	*Latitude (x)*	*Longitude(y)*
Plant	Jl. Adi Sucipto, Karangasem, Surakarta	-7,546771	110,7774344
A1	Sedahromo Lor Kartasura	-7,555661	110,744605
A2	Tisanan Wirogunan Kartasura	-7,545236	110,726411
A3	Kios Mayungan Trunuh Klaten	-7,718148	110,580660
A4	Jalan Raya Delanggu	-7,622274	110,703242
A5	Karangwuni Ceper Klaten	-7,675357	110,662507
A6	Kios Pasar Srago Klaten	-7,711512	110,609565
A7	Jalan RA Kartini Klaten	-7,713042	110,603138
A8	Jalan RA Kartini Klaten	-7,713042	110,603138
A9	Terminal Klaten	-7,713873	110,603776
A10	Jl Raya Sragen - Solo KM 10	-7,477418	110,926050
A11	Jetak, Kec. Sidoharjo, Sragen	-7,437668	110,977394

Table 3. Distance Matrix between Factory and Each Agent

	Plant	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
Plant	0	3751	5627	28869	11720	19102	26036	26661	26661	26675	18108	25162
A1	3751	0	2316	25552	8698	16094	22843	23438	23438	23460	21813	28823
A2	5627	2316	0	25054	8939	16092	22532	23081	23081	23115	23264	30144
A3	28869	25552	25054	0	17208	10197	3269	2541	2541	2591	46537	53712
A4	11720	8698	8939	17208	0	7416	14319	14952	14952	14963	29371	36534
A5	19102	16094	16092	10197	7416	0	7085	7769	7769	7761	36445	43627
A6	26036	22843	22532	3269	14319	7085	0	728	728	690	43524	50705
A7	26661	23438	23081	2541	14952	7769	728	0	0	116	44195	51374
A8	26661	23438	23081	2541	14952	7769	728	0	0	116	44195	51374
A9	26675	23460	23115	2591	14963	7761	690	116	116	0	44193	51373

A10	18108	21813	23264	46537	29371	36445	43524	44195	44195	44193	0	7182
A11	25162	28823	30144	53712	36534	43627	50705	51374	51374	51373	7182	0

Based on data on the distribution of PT Aksara Solopos factory and agent locations, it can be seen in Figure 3. The locations of the most agents are in the Klaten area and the least in the Sragen area

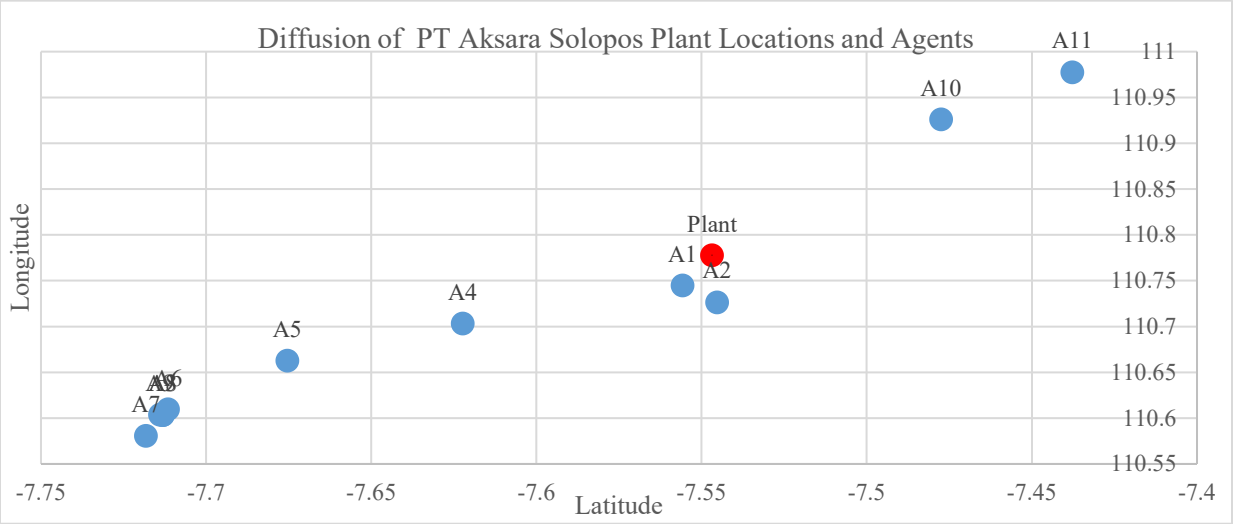

Figure 3. Diffusion of Agent and Factory Locations

5. Results and Discussion

This chapter provides result or research finding and discussion of conducted research.

5.1 Numerical Results

After conducting calculation using haversine formula with Matlab software R2015a, the obtained data are; running time data which is displayed in the Table 4, cluster division data displayed in the Table 5, and the data of the distance of each cluster which is displayed in the table 6.

Table 4. Running Time Data Using Matlab R2015a

Function Name	Calls	Total Time	Self Time*	Total Time Plot (dark band = self time)
CIH_Sweep	1	0.135 s	0.014 s	
Penerapan_CIH_Sweep	1	0.135 s	0.000 s	

Table 5. Cluster Sharing Data

Cluster	Agent	Total *Demand*
1	A1	2548
	A2	
	A8	
	A10	
	A11	
2	A3	2539
	A4	

	A6	
	A9	
	A7	
3	A5	700

Based on the table 5 above, there are 3 clusters with agent division; agents A1,A2,A8,A10,A11 are part of cluster 1 with total demand of 2548; agents A3,A4,A6,A9,A7 are part of cluster 2 with total demand of 2639; and agent A5 is in the cluster 3 with total demand of 700.

Table 6. Distance Data of Each Cluster

Cluster	Distance (km)
1	105,7043598
2	58,2553067892
3	38,2037714
Total Distance	**202,163438**

Furthermore, based on the table 6 above, mileage for cluster 1 is 105.704 km, cluster 2 is 58.25km, and cluster 3 is 38.2 km. Hence, the total distance taken by the three clusters is 202.16 km.

5.2 Graphical Results

After having calculation using haversine formula to process agent diffusion data, and determination of distribution rout using Matlab R2015a, the route sequence for the Solopos newspaper distribution agent is obtained and it is shown in Figure 4, Figure 5, and Figure 6.

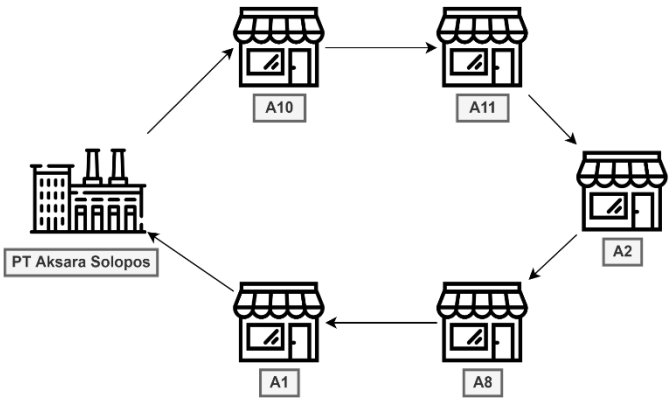

Figure 4 Cluster 1 Newspaper Distribution Route Sequence

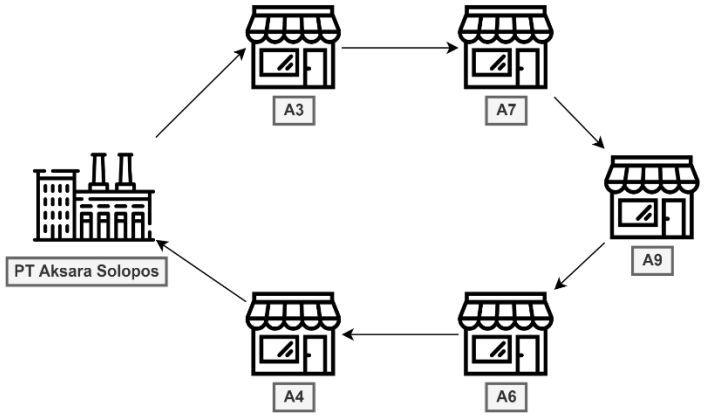

Figure 5. Cluster 2 Newspaper Distribution Route Sequence

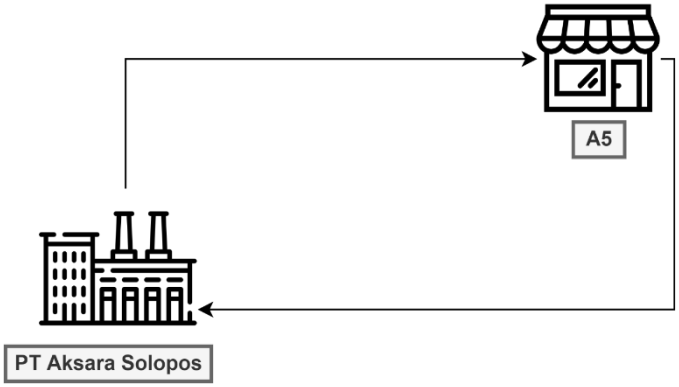

Figure 6. Cluster 3 Newspaper Distribution Route Sequence

5.3 Proposed Improvements

Time of newspaper delivery for each route is 5 hours, starting from 03.00 am until 08.00 am. Based on the calculation using Google Maps, newspaper distribution route is obtained. It is displayed in the figure 7, figure 8, and figure 9. The travel time for each route is as follows:
Travel time for route 1 = 4 hours 3 minutes
Travel time for route 2 = 2 hours 54 minutes
Travel time for route 3 = 1 hour 44 minutes

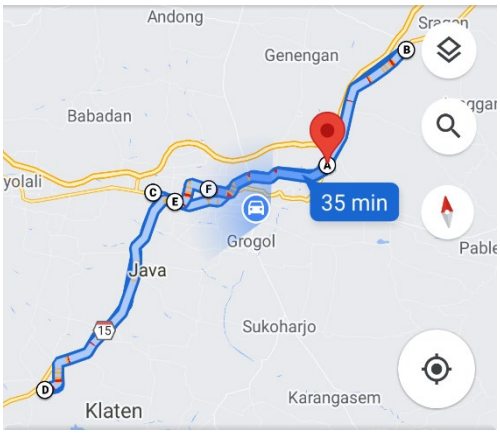

Figure 7. Newspaper Distribution on Route 1

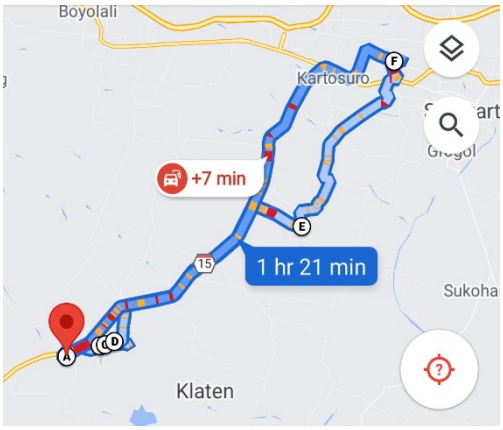

Figure 8. Newspaper Distribution on Route 2

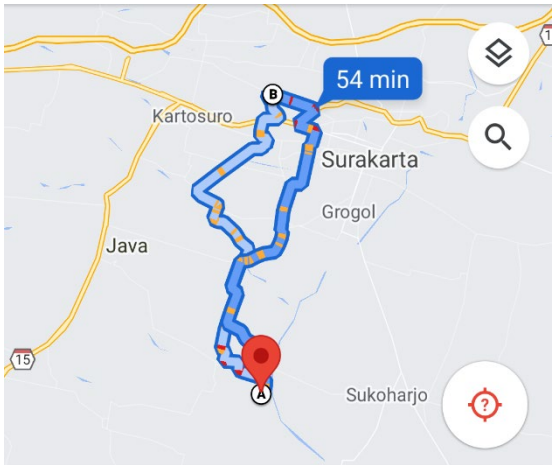

Figure 9. Newspaper Distribution on Route 3

5.4 Validation

Based on the mileage of each route which has been obtained by Cheapest Insertion Heuristic Algorithm and Sweep Clustering, those three mileages are less than 5 hours of newspaper delivery. Therefore, it is in accordance with time windows policy applied by the company.

6. Conclusion

Based on the calculation which has been done by Cheapest Insertion Heuristic Algorithm, travel route of newspaper distribution is divided into 3 clusters; they are cluster 1, 2, and 3. Travel time of newspaper distribution for route 1 is 4 hours 3 minutes, route 2 is 2 hours 54 minutes, and for route 3 is 1 hour 44 minutes. Thus, travelling time for those three routes is less than 5 hours, so it is in accordance with time windows policy of the company.

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Biographies

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