Determining Newspaper Distribution Routes to Reduce Environmental Emissions with Saving Matrix Method Based on Demand Forecasting for Green Logistics

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Abstract

Compared to other businesses, the newspaper industry has a unique distribution strategy that avoids stockpiling goods. This problem is similar to the vehicle routing problem in that it aims to find the best newspaper distribution route while considering future demand forecasts. Demand forecasting using the linear regression approach, with a 5% annual increase in demand. The saving matrix approach with nearest insert, farthest insert, nearest neighbor, sweep, and greedy algorithms determines the ideal distribution path to reduce distribution costs. In the final results, we found routes 1, 2, and 3 to have a total distance of 74.5 km, 80.1 km, and 21 km, respectively. The operation of a fleet of trucks emits 15,992 tons of CO2 per year into the atmosphere.

Keywords
Vehicle Routing Problem, Newspaper Industry, Demand Forecasting, Environmental Emissions, Green Logistic.

1. Introduction
Newspaper industry is one of the industries that must complete the product with a limited cycle time. Newspaper subscribers generally want news that is current and quickly received. The news-editorial team is required to package the news in short enough time to proceed to the editor and printing section of the newspaper. One of the problems that often occur in the Newspaper Industry is the delay in sending newspapers to customers and causing news that is not up-to-date (Putri et al., 2017). Customers prefer to read news through electronic media because it is more accessible and faster to receive. Company XYZ is one of the newspaper industries located in Solo City. Company XYZ wants the delivery of newspapers in the shortest possible time to reach customers quickly so that the news they receive remains up-to-date.

Entities involved in the newspaper industry are suppliers of raw materials, newsagent companies (distributors) of newspapers, storage rooms, newspaper couriers, and customers. The business processes of the newspaper industry are depicted in a vertical flow and a horizontal flow. Vertical flow involves one component of the newspaper company (Ratnasari et al., 2018), while horizontal flow involves other components outside the company but is still related to the newspaper company (Sartika et al., 2018). The business process starts with news editorial to newspaper printing, and this process requires taking materials from the warehouse in the form of ink, plate, and paper. After the newspaper is printed, it will check it for its quality. Newspapers that meet the standards will be sent to agents or retailers for distribution to customers.

Research on the optimization of distribution routes is carried out to shorten distribution routes to save distribution costs (Aqidawati et al., 2018). It can reduce gasoline costs if the distance traveled on the delivery route is shorter (Sumiati et al., 2021). The current condition of the Company XYZ newspaper industry is facing problems that are influenced by the rapid growth of online media. There is a problem of ineffective newspaper distribution routes in the manufacturing cycle process. It is necessary to calculate the optimization of newspaper distribution routes to reach consumers more quickly within the limited cycle time. Determination of distribution routes needs to pay attention to traffic density so that, if possible, congestion can be anticipated (Febriandini et al., 2020). The problems described are an early indication of supply chain problems, so further investigations need to be carried out. It is necessary to boost supply chain performance system in the Newspaper Industry to maximize the supply chain system (Jodinesa et al., 2019). Every year the volume of vehicles increases. In 2019, the number of vehicles increased by 5.3% from the previous year. Increasing the volume of vehicles can increase traffic density, resulting in delays in the delivery of newspapers. The business process of the Newspaper Industry is show at figure 1.

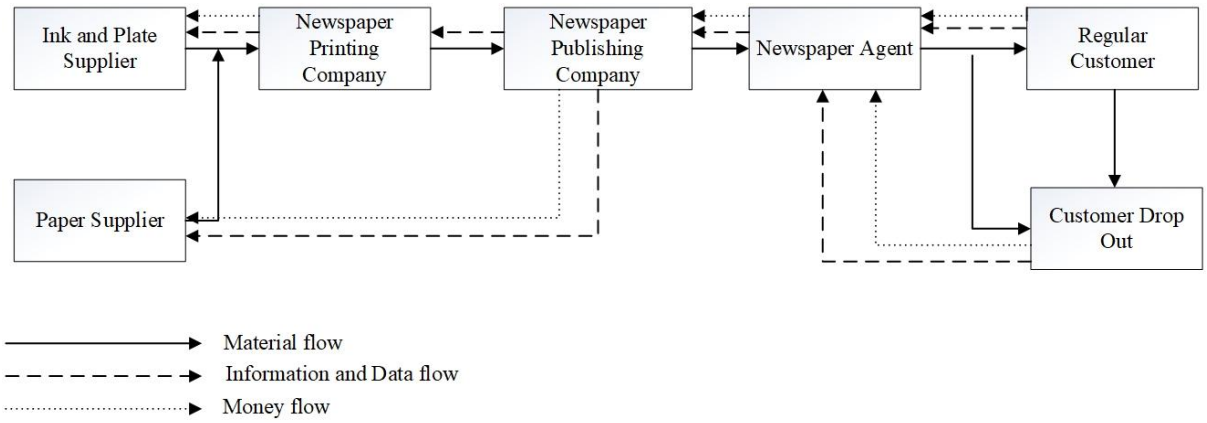

Figure 1. Business Processes of Newspaper Industry

Based on the picture of the newspaper business process flow above, it can be seen that the raw material supplier entity consists of newsprint, ink, and plate, which are the primary raw materials ordered by newspaper printing companies. Newspaper printing company entities focus on the production of newspapers which consist of pre-printing, printing, and post-printing processes. Newspaper publishing entities are tasked with ordering paper raw materials and making news content for newspaper printers for further printing. The newsagent entity is in charge of distributing newspapers to regular customers. Finally, the customer entity is the entity that buys the newspaper and reads the newspaper (Arsyifa, 2019).

Adam et al. (2020) conducted a previous that was comparable to this one on selecting the best path for newspaper distribution. One of the issues with a slow distribution process is choosing the incorrect route (Adam et al., 2020). The research "Determination of Routes for Daily Newspaper Product Distribution with Saving Matrix Methods" raises the issue of optimal routing with the number of vehicle capacity constraints. This study has not considered transportation constraints when the level of vehicle traffic in Solo City is relatively high. In general, the volume of vehicles that pass on the streets of Solo City is increasing every year. The current research will raise the issue of optimizing newspaper distribution routes based on demand forecasting to reduce environmental emissions.

Based on the foregoing description, the goal of this study is to establish the best path for distributing Company XYZ newspaper while taking into account the increasing demand each year.

2. Literature Review

Distributing newspapers from newspaper publishing companies and agents to customers is no longer a new thing in the newspaper manufacturing industry. In distributing, the Company XYZ also experienced a slow distribution process due to the inaccurate route determination and the high cost of distributing newspapers. This is due to the absence of a definite distribution route when sending newspapers to agents, so the route is less than optimal and increases distribution costs.

Saraswati et al. (2017) conducted a study entitled "Solving the Capacitated Vehicle Routing Problem by Using the Sweep Algorithm for Determining Newspaper Distribution Routes". This research raises the issue of newspaper distribution routes that are not fixed so that the distribution costs of Company XYZ are high. Another research related to routing has also been carried out by Adam et al. (2020) with the title "Determination of Routes for Daily Newspaper Product Distribution with Saving Matrix Methods". The study also raised the issue of newspaper distribution routes with constraints on the number of vehicle capacities. It did not take into account the level of traffic flow of the transportation traversed. This study will now raise the issue of optimizing the distribution route of the Company XYZ in the Klaten-Kartasura area by comparing the routing results between previous studies using the sweep algorithm and the saving matrix method in the research conducted by Adam et al., taking into account demand forecasting.

Emissions are air pollutants from activities that use fuel (primary emissions) and electrical power (secondary emissions) (Wulandari et al., 2013). According to Wulandari et al. (2013), the emission factor is a coefficient that connects activities with emission sources. This factor can express emissions for each unit based on fuel (Zhang et al., 2020). Meanwhile, FES is a specific emission factor that refers to CO2 per particular unit. However, data is also needed to find out CO2 emissions that consume a lot of fuel (Zhang et al., 2020). Table 1 shows calorific values of Indonesian fuel and table 2 shows default CO2 emission factor.

Table 1. Calorific Values of Indonesian Fuel

Fuel	Calorific Value		Use
Premium	33 x 10^{-6} TJ/liter	-	Motor Vehicle
Solar (HSD, ADO)	36 x 10^{-6} TJ/liter	9.063 Kkal/liter	Motor Vehicles, power plants

Information: HSD: High-Speed Diesel, ADO: Automotive Diesel Oil

Table 2. Default Co2 Emission Factor

Fuel Type	Default (kg/TJ)	Lower	Upper
Gasoline	69.300	67,500	73,000
Gas/Diesel Oil	74.100	72,600	74,800

Source: Ministry of Environment, 2012

3. Methods

Research on optimizing newspaper distribution routes at XYZ company was carried out by applying the saving matrix method to calculate the shortest route. The problem raised requires an operational decision level where the stakeholders are XYZ company and newsagents in Kartasura-Klaten. The method applied from previous research is to consider demand forecasting with the assumption of a 5% increase in demand. Demand data, agent data, distribution distance data will be utilized to define product distribution channels in the marketing area by determining the distribution route to be traveled and the number of cars to be employed based on vehicle capacity in order to find the shortest route with the lowest transportation costs. Distance data will be formulated into a matrix and calculated saving matrix for each combination of two customers (Rosanti et al., 2019). Demand data is interpreted to determine how many newspapers will be distributed by each agent. Agent data is interpreted to determine the distribution route flow (Saputra et al., 2017). Distribution cost data are interpreted to calculate the amount of distribution cost savings after optimizing distribution routes (Nugraha et al., 2020). The distance data between agents is used to determine the optimal routing path.

As exhaust emissions are released into the air, greenhouse gases (GHG) are the most significant contributor to emissions in the form of carbon emissions. Until now, it is estimated that the concentration of CO2 in the atmosphere is the most dominant concentration of all greenhouse gas effects (Wang et al., 2019). The carbon footprint, or what in English is called Greenhouse Gas Emission, is a measure that calculates the total amount of direct or indirect carbon dioxide emissions (Pulansari et al., 2021). This carbon dioxide emission can be caused by activities or accumulation from products in everyday life. Examples of primary carbon footprints can be obtained from burning fossil fuels when using vehicles and transportation (Nugraha et al., 2019). In this study, Greenhouse Gas Emissions were calculated to determine how much carbon dioxide emissions were produced in the distribution process of XYZ Company script that can impact environmental cleanliness.

The search for problems that occur in the newspaper industry begins with a review of some relevant literature on the case study of XYZ Company. Based on the literature review, one of the problems raised to be the focus of research is taken, namely the distribution routing section. It is necessary to calculate the optimization of newspaper distribution routes to reach consumers more quickly within the limited cycle time. The existence of an optimal route will reduce the company's distribution costs by implementing the shortest route to distribute newspapers to customers. Data collection was carried out using several references to previous research literature. Figure 2 is a flow of research data collection and processing.

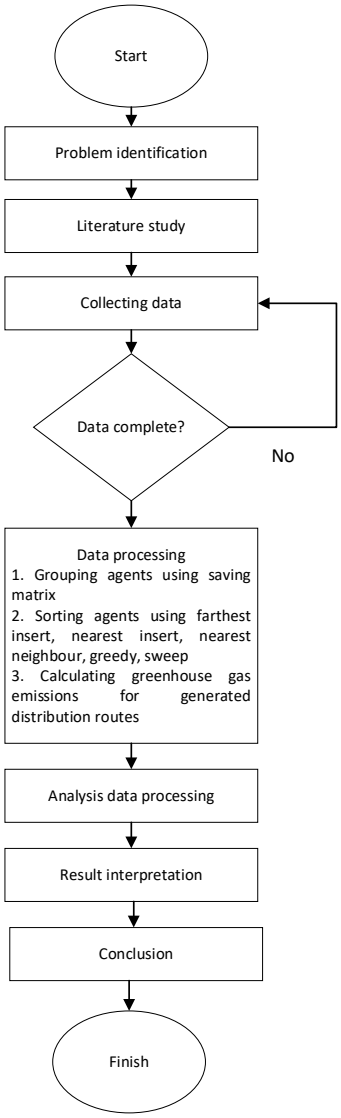

Figure 2. Research Methodology Flowchart

Saving matrix methods are used by applying the Nearest Neighbor method. The modification of this study is only to consider the Nearest Neighbor method and not to consider the Nearest Insert, Farthest Insert, Greedy, and Sweep Procedures methods. The reference model will be used in the following steps (Sarjono, 2014):

a. First, all of the vehicles are completely vacant. Then, this approach puts the nearest unvisited customers into the route one by one, starting with the first car.
b. During the customer insertion process, the vehicle must not exceed its maximum capacity.
c. Then the same process is performed for the following vehicle until all vehicles are total or all customers are visited.
d. The Nearest Neighbor method has the advantage of having less iterations in order to find the best solution for combinatorial optimization issues.
e. However, certain cities that are not too far away can be visited after traveling to them, resulting in longer distances and higher costs.

1. Identify the distance matrix
   This step requires the distance between warehouse to each store and distance between the stores. Distance calculations can be done after the coordinates of each location are known. The distance matrix formula is as follows:

$$J(1,2) = \sqrt{(X_1 - X_2)^2 + (Y_1 - Y_2)^2} \quad \text{.....(1)}$$

   Description:
   (X1, Y1) = Location Coordinate Point 1
   (X2, Y2) = Location Coordinate Point 2
2. Identify savings metrics
   At this stage, each shop will be visited exclusively by one vehicle. The savings matrix represents the savings that can be made by combining two retailers into one route. The savings matrix formula is as follows:

$$S\ (x,y) = J(g,x) + J\ (g,y) - J(x,y) \quad \text{.....(2)}$$

   Where S(x,y) is the distance saving by combining x and y routes into one.
3. Allocate retailers to routes
   To optimize savings, start by combining the largest savings value. The combination of customers is formed into the vehicle travel route at this step.
4. Sort destination retailers in predefined routes
   Specifies the order of visits after the retailer's allocation to the route has been determined. The steps to determine the order are using the Nearest Neighbor algorithm. Nearest Neighbor method consists of several steps in this method are as follows:
   a. Begin with any node as the start of the path.
   b. Locate the node closest to the last node added to the path.
   c. Repeat Step 2 until all nodes are in the path.
   d. Finally, merge the first and last nodes.

The steps for using the saving matrix method are as follows (Xing et al., 2016):

a. Begin at the depot, then looking for unvisited agents who have the shortest distance from the depot as the first location.
b. Other agents who have the closest distance to the pre-selected agent and the number of deliveries does not exceed the vehicle's capacity.
   - If an agent is selected as the next stop and there is a remaining vehicle capacity, return to step (2).
   - If the vehicle has no remaining capacity, return to step (1).
   - If no location is selected because the number of deliveries exceeds the vehicle capacity, return to step (1). It starts again from the depot and visits the unvisited agents who have the closest distance.
c. If all customers have been visited exactly once then the algorithm ends.

The steps taken after determining the optimal route are calculating CO_2 emissions resulting from the newspaper distribution process at Company XYZ. The equation for calculating emissions refers to the Ministry of Environment (2012) for different fuels having different calorific values. The emission equation is written as follows:

Greenhouse Gas Emissions (Kg/Year) = KE x FE x NK……..(3)

Description:
KE = Energy Consumption (TJ/Year)
FE = Emission Factor (TJ/lt)
NK = Calorific Value (kg/TJ)

4. Data Collection

This study uses secondary data obtained from previous studies. Where this data is taken from the Company XYZ daily distribution in 2017, then demand forecasts are carried out using the linear regression method to obtain demand forecasts for 2022. The data are distribution area data, demand forecast data, distribution cost data, and vehicle capacity.

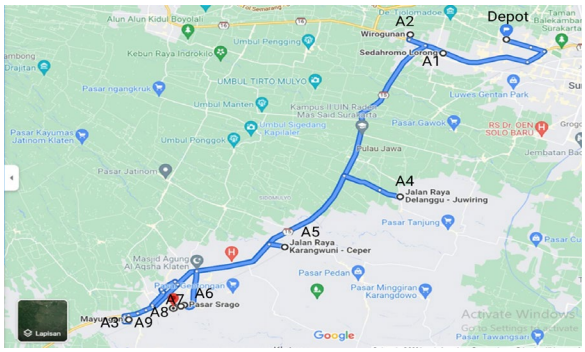

Figure 3. Distribution Area Data

Figure 3 shows the initial route that must be taken by the vehicle to deliver newspapers from Company XYZ script. Table 3 shows the coordinates for each location:

Table 3. Distribution Area Coordinate Data

Symbol	Region Name	Address	Coordinates	Daily Demand
A0	Depot	Jln. Adi sucipto no,190	-7.546103668484427, 110.77940102574044	
A1	Abdul Basyir	Sedahromo lor, Kartasura	-7.554687366232205, 110.74582271039415	**789**
A2	Yudistira	Tisanan, Wirogunan, Kartasura	-7.538825089211378, 110.72733426806714	**770**
A3	Icah	Kios Mayungan Trunuh Klaten	-7.7182293086721305, 110.57862818280104	**575**
A4	Sulomo	Jalan Raya Delanggu	-7.620843584941927, 110.69968435896186	**671**
A5	Handoyo	Karangwuni, Ceper, Klaten	-7.674438176133582, 110.65400652388567	**775**
A6	Multimediawara	Kios Pasar Srago, Klaten	-7.711265562799768, 110.60959761225192	**585**
A7	Ibra	Jalan RA. Kartini, Klaten	-7.712818049109827, 110.60339917692804	**709**
A8	Handayani	Jalan RA. Kartini, Klaten	-7.71365795844846, 110.6016557411061	**495**
A9	Sami	Terminal Klaten	-7.713249259225728, 110.60390783862321	**575**

After getting the coordinates of the newspaper distribution area, the distance between the depots and the agents can be projected in the following figure. Figure 4 shows the distance from agent to depot.

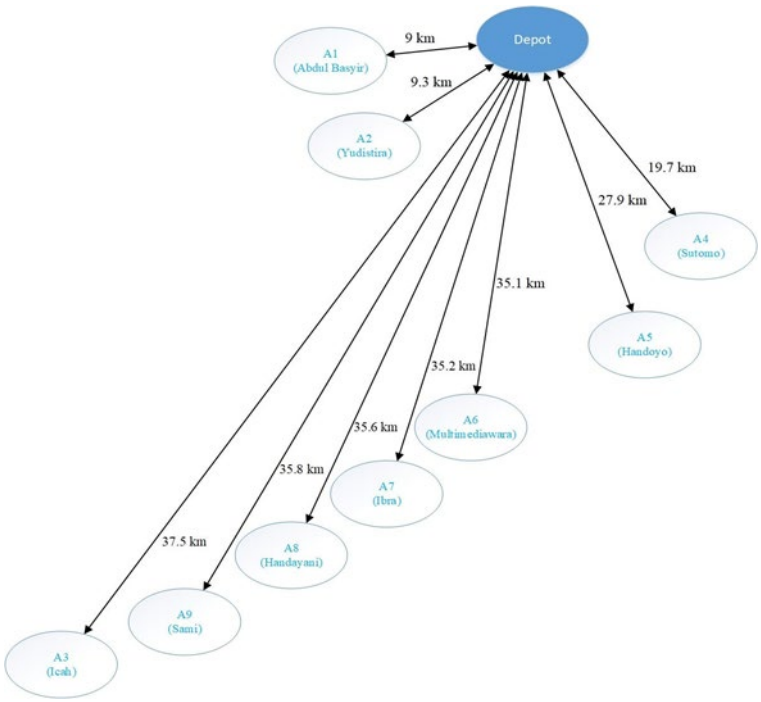

Figure 4. Distance from Agent to Depot

Data processing starts from the calculation of demand forecasting for 2022 using the linear regression method. Table 4 shows result of demand forecasting data.

Table 4. Demand Forecasting Data

Demand Forecast using Linear Regression

PERIOD (t)	ACTUAL DEMAND (A)	t.A	t^2	DEMAND FORECAST (D)	ERROR	ABSOLUTE ERROR	RSFE	MAD	TRACKING SIGNAL	MSE	MAPE
1	1.712.945	1712945	1	1.708.489	4456	4455,80	4455,80	4455,80	1,00	19.854.137,43	0,26%
2	1.798.592	3597185	4	1.800.755	-2163	2162,59	2293,21	3309,20	0,69	4.676.808,75	0,12%
3	1.888.522	5665566	9	1.893.020	-4499	4498,62	-2205,42	3705,67	-0,60	20.237.598,16	0,24%
4	1.982.948	7931792	16	1.985.286	-2338	2338,17	-4543,59	3363,80	-1,35	5.467.038,60	0,12%
5	2.082.095	10410477	25	2.077.552	4544	4543,59	0,00	3599,75	0,00	20.644.179,31	0,22%
6				2.169.817	Jumlah					**5.906.646,85**	**0,19%**
7				2.262.083							
8				2.354.349							
SUM	9465102	29317964	55								
A rata-rata	1893020										
t	5										
t rata-rata	3,00										
Slope (b)	92265,64										
Intercept (a)	1616223,56										

Annual Dema 2.169.817
Daily Demar 5944,705228

The table above shows the results of forecasting the demand for Company XYZ in 2017 with the assumption of an increase in demand by 5% every year. In the 6th period (Year 2022) it is estimated that the number of requests for newspapers in that year is 2,169,817 copies. This means that the daily demand for newspapers in 2022 is estimated at 5,944 copies.

Table 5. Distribution Cost Data

Distribution cost data	
1 Liter Gasoline	= 10 Km
1 Liter Gasoline	= IDR 10,400.00

The distribution cost considered in this study is the cost of gasoline used by the vehicle as shown at table 5. Where 1 liter of gasoline can be used to cover a distance of 10 km at a cost of IDR 10,400.00.

Tabel 6. Vehicle Capacity Data

Vehicle 1	2500 copy
Vehicle 2	2000 copy
Vehicle 3	2000 copy

In this study, there are three choices of vehicles that can be used to transport goods. Table 6 shows that 1 vehicle with a capacity of 2,500 copies and 2 vehicles with a capacity of 2,000 copies. Table 7 shows a result of fuel consumption data.

Table 7. Fuel Consumption Data

Route	Distance (Km)	Fuel Consumption (liter/year)	Total Cost (Year)
Route 1	74,52	2,719.98	IDR 28,287,792.00
Route 2	80,10	2,923.65	IDR 30,405,960.00
Route 3	21	766.50	IDR 7,971,600.00

5. Result and Discussion

In this study, observations were made on the daily distribution of Company XYZ in February 2017. The initial data used were the distance between agents and number of requests for each agent, as shown in Table 5. The saving matrix method was used to reduce the number of routes. This method can form a route and a sequence of stopping points in one route. The initial step used is to identify the distance matrix between warehouses to each agent and the distance between stores using the coordinates shown in Table 8.

Table 8. Distance between Depot and Agent (km)

DEPOT		A 1	A 2	A 3	A 4	A 5	A 6	A 7	A 8	A 9
A1	9	0								
A2	9,3	2,7	0							
A3	37,5	28,8	29,1	0						
A4	19,7	14,8	15,1	22,2	0					
A5	27,9	19,5	19,8	12,2	11,4	0				
A6	35,1	26,4	26,7	5,7	18,3	9	0			
A7	35,2	26,5	26,8	4,5	18,4	9,6	0,24	0		
A8	35,6	26,9	27,2	4	18,8	10	0,6	0,45	0	
A9	35,8	27,1	27,4	4,1	19	10,2	0,8	0,65	0,17	0

The next step is to determine the saving matrix based on the assumption that each agent will only be visited by one truck. As a result, there will be nine distinct routes, each with a single destination.

S(x,y) = J(G,x) + J(G,y) - J(x,y)
S(x,y) = 9 + 9,3 - 2,7
= 15,6 km

Based on the above calculation, the distance that can be saved from agent 1 to agent 2 is 15.6 km. By using the same formula, the results of the calculation of distance savings are obtained shown at table 9.

Table 9. Distance Saving Calculation Results (km)

DEPOT		A 1	A 2	A 3	A 4	A 5	A 6	A 7	A 8	A 9
A1	9	0								

DEPOT		A 1	A 2	A 3	A 4	A 5	A 6	A 7	A 8	A 9
A2	9,3	15,6	0							
A3	37,5	17,7	17,7	0						
A4	19,7	13,9	13,9	35	0					
A5	27,9	17,4	17,4	53,2	36,2	0				
A6	35,1	17,7	17,7	66,9	36,5	54	0			
A7	35,2	17,7	17,7	68,2	36,5	53,5	70,06	0		
A8	35,6	17,7	17,7	69,1	36,5	53,5	70,1	70,35	0	
A9	35,8	17,7	17,7	69,2	36,5	53,5	70,1	70,35	71,23	0

After calculating the distance savings, the next step is to allocate vehicles or routes with the initial assumption of 9 different routes. Agent allocation can be combined with existing vehicle capacity limits. The combination starts from the most enormous savings to save as much distance as possible. Based on calculations in the allocation of agents to routes or vehicles, the results of the calculation of agent allocations to routes or delivery vehicles are known with three delivery routes shown at table 10.

Table 10. Saving Matrix Grouping Results

Route	Agent	Capacity Fulfilled	Remaining Capacity
Route 1	A8,A9,A7,A4	2.450	50
Route 2	A6,A5,A3	1.935	65
Route 3	A2,A1	1.559	441

After the route allocation is made, next step is to determine the order of delivery using the Nearest Insert, Farthest Insert, Nearest Neighbor, Greedy, and Sweep methods. This is done because the agents are in a group of routes that are still random, so they need to be sorted. It is assumed that each agent takes the Warehouse-Agent-Warehouse route, then shipments are sorted by method and route as shown in the table below. They then formed routes 1, 2, and 3 with the help of google maps. Table 11 shows distance recapitulation and delivery order based on method.

Table 11. Distance Recapitulation and Delivery Order Based on Method

Route	Delivery Order	Method	Total Distance (Km)
Route 1	Depot-A 4-A 7-A 8-A 9-Depot	Nearest Insert	74.5
	Depot-A9-A4-A8-A7-Depot	Farthest Insert	109.3
	Depot-A4-A7-A8-A9-Depot	Nearest Neighbour	74.5
	Depot-A4-A7-A8-A9-Depot	Sweep	74.5
	Depot-A4-A7-A8-A9-Depot	Greedy	74.5
Route 2	Depot-A5-A6-A3- Depot	Nearest Insert	80.1
	Depot-A3-A6-A5- Depot	Farthest Insert	80.1
	Depot-A3-A6-A5- Depot	Nearest Neighbour	80.1
	Depot-A5-A6-A3- Depot	Sweep	80.1
	Depot-A5-A6-A3- Depot	Greedy	80.1
Route 3	Depot-A1-A2- Depot	Nearest Insert	21
	Depot-A2-A1- Depot	Farthest Insert	21
	Depot-A1-A2- Depot	Nearest Neighbour	21
	Depot-A2-A1- Depot	Sweep	21
	Depot-A1-A2- Depot	Greedy	21

The minimum total distance is generated based on calculations using Farthest Insert, Nearest Insert, Nearest Neighbor, Greedy, and Sweep. Based on table 8, route 1 has a total distance of 74.5 km, route 2 has a distance of 80.1 km, and route 3 has a distance of 21 km. The route can be applied with the assumption that there are no agent changes

and current traffic sign congestion constraints. Furthermore, the outcomes achieved are limited to Klaten-Kartasura area.

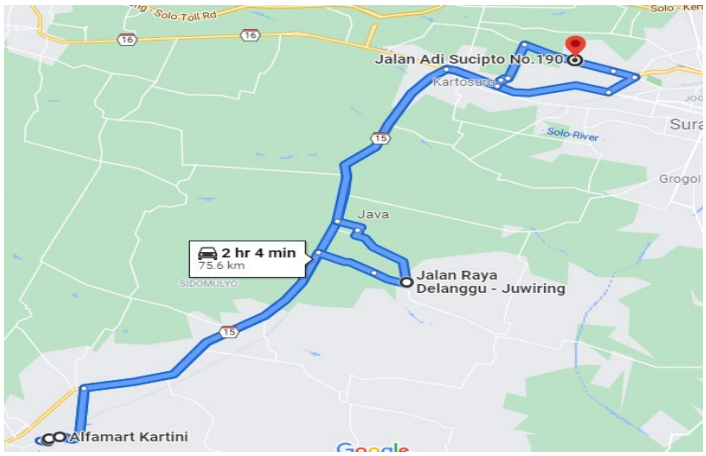

Figure 5. Route 1 Cluster Determination Using Google Maps

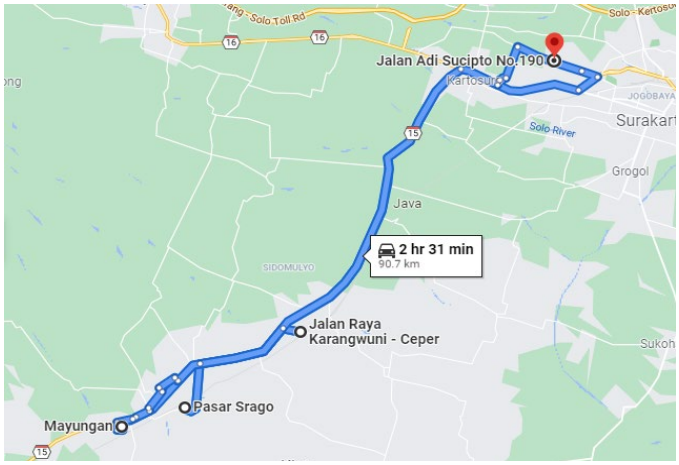

Figure 6. Route 2 Cluster Determination Using Google Maps

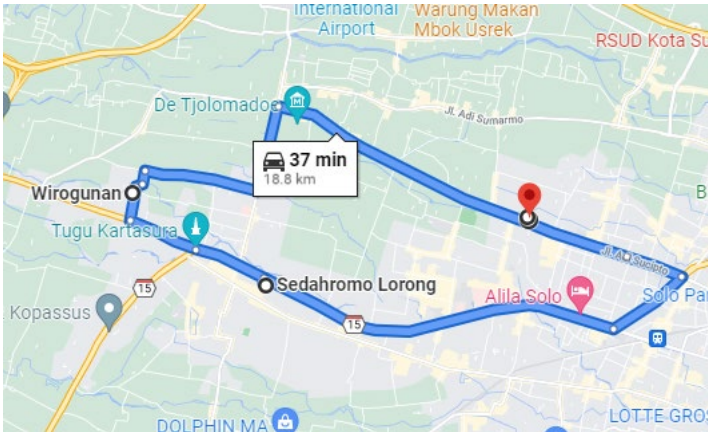

Figure 7. Route 3 Cluster Determination Using Google Maps

Based on the settlement with the Saving Matrix method, the route with the total travel time and distance is obtained as follows. Figure 5 shows route 1 cluster determination, figure 6 shows route 2 cluster determination, and figure 7 shows route 3 cluster determination. Table 12 shows distribution line distance recapitulation.

Table 12. Distribution Line Distance Recapitulation

Route	Delivery Order	Total	Total Distance (Km)	Time
Route 1	Depot-A4-A7-A8-A9-Depot	2.450	74.5	2 Hours 4 Minutes
Route 2	Depot-A5-A6-A3-Depot	1.935	80.1	2 Hours 31 Minutes
Route 3	Depot-A1-A2-Depot	1.559	21	37 Minutes

Based on the results of the total distance obtained, it can be calculated distribution costs for each route at table 13.

Table 13. Distribution Cost Recapitulation

Route	Total Fuel	Distribution Cost
Route 1	7.45	IDR 77,840.00
Route 2	8.01	IDR 83,304.00
Route 3	2.1	IDR 21,840.00

Based on the results of the recapitulation of the amount of gasoline and distribution costs, the calculation of carbon emissions for each route is carried out using the following formula:

Greenhouse Gas Emission (Kg/year) = KE x FE x NK

Noted :

KE = Energy consumption
FE = Emission Factor
NK = Calorific Values

So that the calculation is obtained :

Greenhouse Gas Emission (Kg/year) = KE x FE x NK
= 6410.13 x 0.000036 x 69300
= 15.992 CO_2 / Year

Based on the above calculation, the total gas emission produced by the fleet used to distribute newspapers is 15,992 CO2/year.

6. Conclusions

Three optimal newspaper distribution routes were obtained based on data processing regarding newspaper demand forecasting and vehicle routing problem solving. 3 These routes have been arranged in order so that the total distance traveled for route 1 is 74.5 km, route 2 is 80.1 km, and route 3 is 21 km with a total of 15.992 kilograms of carbon emissions produced from the three vehicles used per year. This article can be developed further by increasing the reachable agent data. XYZ Company script can use a proposal designed to determine the distribution route of newspapers to agents, but this research is not the most optimal. Also, this study only considers economic and environmental factors by calculating fuel consumption, has not considered social factors, and has not calculated the value of electricity consumption. Then in the future, the company can carry out sustainable development by using more environmentally friendly fuels to reduce the resulting carbon emissions. It would be better to consider social factors and calculate the value of electricity consumption to apply the concept of sustainable supply chain management.

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