

Determining the Optimal Route for Newspaper Distribution to Reduce Environmental Emissions for Green Logistics Using the Saving Matrix and Nearest Neighbor Methods Case Study: XYZ Ltd. Surakarta

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Abstract

In the digitalization era, newspaper customers choose to access electronic news because it is received more quickly and does not require a lot of money to access the news. The Newspaper Industry requires an optimal distribution system with the shortest route to save transportation costs and speed up newspapers reaching customers. Traffic density is a factor that can slow down the newspaper distribution process. There are emission factors from the distribution process and affect the air quality in the environment. The factors of traffic density and greenhouse gas emissions need to support the concept green distribution and green logistics at XYZ Ltd. Surakarta. This study to provide proposed optimal distribution route by adjusting the level of traffic density and paying attention to greenhouse gas emission factors using saving matrix method and nearest neighbor method. The results of this study indicate the distribution route with a total distance of 28.6 km with a distribution time of 114 minutes. The company save 31.5 hours/month. With the optimal total mileage obtained, the company produces $2,3875 \times 10^3$ kg of CO₂/year and only spends IDR 29,744.00/day for gasoline costs, where the emission results and operating costs are relatively low.

Keywords

Distribution Route, Environmental Emissions, Nearest Neighbor, Saving Matrix, 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 a short enough time to proceed to the editor and printing section of the newspaper. One of the problems that often occurs in the Newspaper Industry is the delay in sending newspapers to customers and causing news that is not up to date. Customers prefer to read news through electronic media because it is more accessible and faster to receive. With decreasing demand and number of readers switching to digital based newspapers, the evaluation of newspaper production needs to be reviewed in order to adapt to market conditions (Febriandini et al., 2019). XYZ Ltd

Surakarta is one of the newspaper industries located in the city of Solo. XYZ Ltd wants the delivery of newspapers in the shortest possible time so that newspapers can 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 (warehouses), newspaper couriers, and customers. Warehouse is a warehousing or logistics system used by companies to store and provide goods. The system in the warehouse provides information about the availability or stock of goods, the condition of the goods to the status of delivery of goods and is an important factor of production in managing the flow of goods (Dianto et al., 2020). The business processes of the newspaper industry are depicted in a vertical flow and a horizontal flow (Sartika et al., 2018). Vertical flow means that it involves one component of the newspaper company, while horizontal flow involves other components outside the company but is still related to the newspaper company. The business process starts with news editorial to newspaper printing, this process requires taking materials from the warehouse in the form of ink, plate and paper. After the newspaper finished printing, Newspaper quality will be checked. Newspapers that meet the standards will be sent to agents or retailers for distribution to customers. The business process of the Newspaper Industry is shown in figure 1:

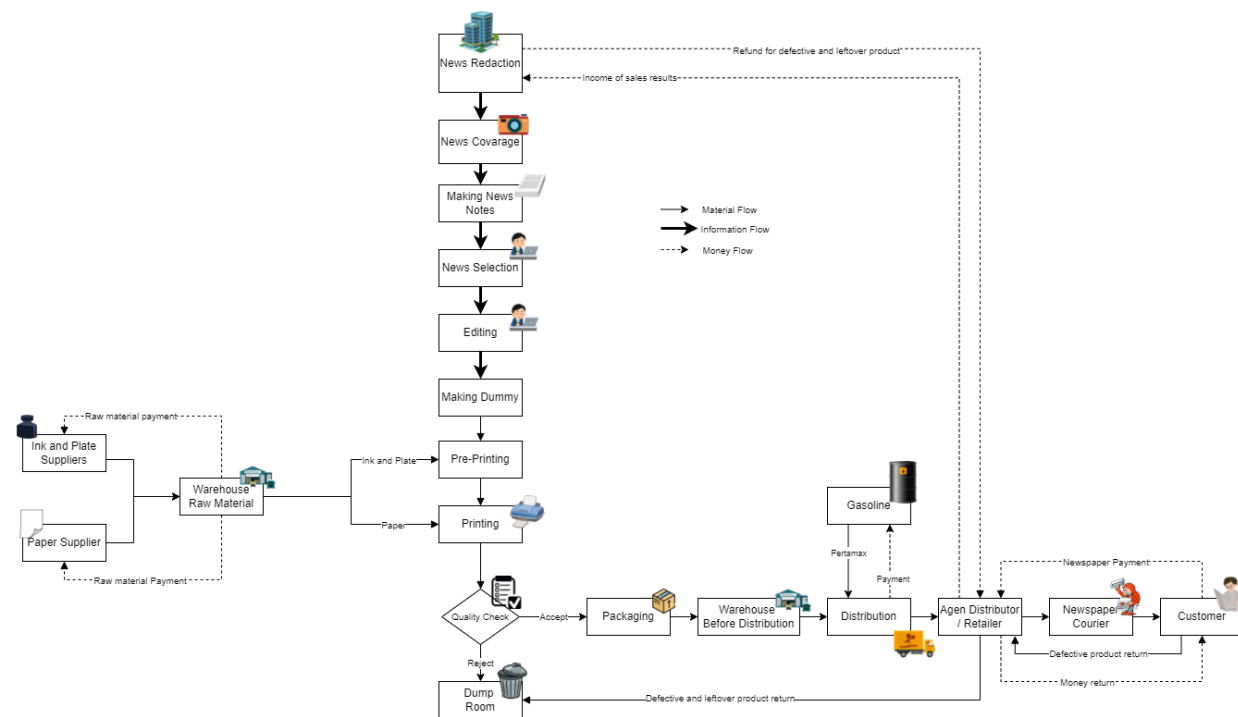


Figure 1. Newspaper Industry Business Process

Research on optimization of distribution routes is carried out with the aim of shortening distribution routes so that distribution costs can be saved (Nugraha et al., 2020). Gasoline costs can be reduced if the distance distribution on the delivery route is shorter (Iriani and Asmara, 2020). The condition of the newspaper industry of XYZ Ltd. Surakarta is currently facing problems that are affected by the rapid growth of online media. In the manufacturing cycle process there is a problem of ineffective newspaper distribution routes. It is necessary to calculate the optimization of newspaper distribution routes so that newspapers can reach consumers more quickly within the limited cycle time (Saputra, et al., 2018). Determination of distribution routes needs to pay attention to traffic density so that, if possible, congestion can be anticipated (Febriandini and Sutopo, 2020). The absence of a determined optimal route results in a lack of efficiency in terms of distance and time of newspaper distribution. It is hoped that with the optimal route, the newspaper distribution process can run efficiently in terms of distance and time (Tisen, 2013). The problems described

are an early indication of the occurrence of supply chain problems so that further investigation is necessary. It is necessary to improve the supply chain performance system in the Newspaper Industry so that the supply chain system can be maximized (Aqidawati et al., 2018). On the other hand, increasing vehicle volume can increase traffic density which results in delays in newspaper delivery. The purpose of this study is to propose an optimal distribution routing by adjusting the level of traffic density and paying attention to greenhouse gas emission factors.

2. Literature Review

A previous study similar to the study of determining the optimal route of newspaper distribution was conducted by Adam et al. in 2020. One of the problems with slow distribution process is determination of the wrong route (Adam et al., 2020). The research "Determination of Routes for Daily Newspaper Product Distribution with Saving Matrix Methods" raises the problem of route optimization in the presence of constraints on the number of vehicle capacities. This study has not considered transportation constraints when the level of vehicle traffic in Solo City is quite high. In general, volume of vehicles that pass on the streets of Solo City is increasing every year.

Determination of the optimal route in this study using saving matrix method and nearest neighbor method. The saving matrix method has the advantage of being easy to solve complex distribution line problems to get the optimal route (Sianipar et al., 2017). The nearest neighbor method is a method that determines the route starting with the route closest to the distribution center and the next route according to the closest route from the last visited customer. The shortest route based on the calculation results will be used as a reference as the optimal distribution route to save transportation costs (Sumiati et al., 2021).

Other problems arise related to the increase in the consumption of energy, fuel, and motor vehicles, which have an impact on decreasing environmental quality (Li et al., 2015). The negative impact of high CO₂ emissions is a decrease in air quality. The distribution process cannot be separated from transportation using vehicles. The vehicles used of course emit gas emissions that will have an impact on the environment, especially on air quality (Pulansari et al., 2021). This study seeks to consider CO₂ gas emissions and traffic density levels to obtain the optimal distribution route. In addition, calculation of CO₂ emissions is carried out to find out how much emission from the distribution process of XYZ Ltd. Surakarta and make suggestions to XYZ Ltd. Surakarta for the development of activities that support green distribution and green logistics activities (Nugraha et al., 2019). Emissions are air pollutants from activities that use fuel and electrical power (Wulandari et al., 2013). The emission factor is a coefficient that connects activities with emission sources (Wulandari et al. 2013). Where the idea of green distribution and green logistics is basically a process or system that has minimal impact on the environment or does not have a negative impact on the environment (Amaranti et al., 2017). Green distribution and green logistics include direct delivery to consumers, use of alternative fuel vehicles and distributing products in batches (Yuniarti et al., 2018). Therefore, this study considers the calculation of greenhouse gas emissions to provide proposals that not only have a positive impact on the company, but also have a positive impact on the environment.

3. Methods

Research on the optimization of newspaper distribution routes at XYZ Ltd. Surakarta is carried out by applying the saving matrix method to calculate the shortest route and only considers the nearest neighbor method. The problem raised requires an operational decision level where the stakeholders are XYZ Ltd. Surakarta Industry and XYZ Ltd. Surakarta newspaper distribution agent. Modification of the method was carried out from the research of Adam et al. in 2020 taking into account traffic levels and newspaper distribution times. Demand data, agent data, distribution distance data obtained from Adam et al in 2020. The data will be used to determine product distribution channels in the marketing area by determining the distribution route to be traversed and the number of vehicles based on vehicle capacity to obtain the shortest route and minimum transportation costs. The assumption data used is vehicle speed data as a traffic density parameter. Distance data will be formulated into a matrix and calculated saving matrix for each combination of two customers (Rizwanullah and Nilofer, 2018). 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 (Wang et al., 2019). Distribution cost data are interpreted to calculate the amount of distribution cost savings after optimization of distribution routes. The distance data between agents is used to determine the optimal route (Sarjono, 2014).

The search for problems that occur in the newspaper industry begins with a review of some relevant literature on the case study of XYZ Ltd Surakarta. Based on the literature review, one of the problems that will be raised to be the

focus of research is taken, namely the distribution route section. It is necessary to calculate the optimization of newspaper distribution routes so that newspapers can 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 by taking data from several references to previous research literature. The following is the flow of research data collection and processing shown in figure 2:

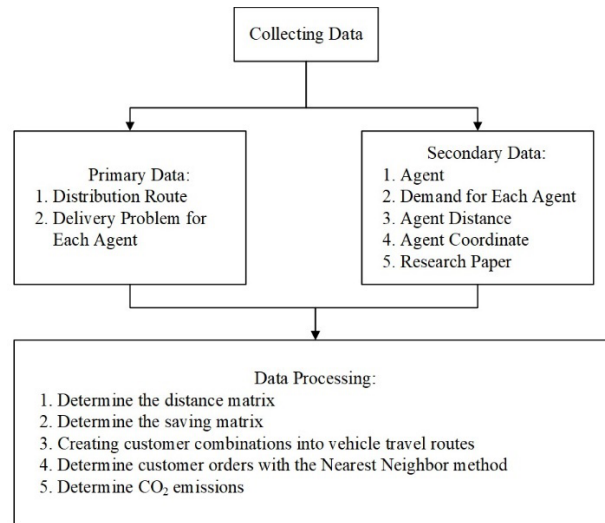


Figure 2. Data Collection and Processing

Saving matrix methods used by applying the Nearest Neighbor method. The modification of this research is to only consider nearest neighbor method. The reference model will be used in the following steps:

1. The vehicle is not loaded for the initial condition. The first vehicle started the route and unvisited customers unto the route one by one with the nearest neighbor method.
2. The vehicle must not carry more than the maximum capacity, during the insertion process of distribution to customers.
3. The process is carried out continuously on to the next vehicle until the vehicle load is full and all customers have been visited.
4. The benefit of the nearest neighbor algorithm is the iteration is shorter so that it provides the optimum value for solving combinatorial optimization problems.
5. Several cities that are close enough can be distributed and then visited, resulting in longer distances and higher costs.

Research on product distribution route optimization uses the savings matrix method with several methods to minimize distribution distances (Rosanti et al., 2019). Modification of the method applied is to consider the level of traffic and newspaper distribution time. The steps for using this method are (Pujawan and Mahendrawati, 2010):

1. Identifying the distance matrix

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

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

Description:

(X1, Y1) = Location Coordinates 1

(X2, Y2) = Location Coordinates 2

2. Identify savings matrix

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:

$$S(x,y) = J(g,x) + J(g,y) - J(x,y) \dots \dots \dots (2)$$

Where $S(x,y)$ is the distance saving by combining x and y routes into one.

3. Allocating retailers to routes

Combining starting from the largest savings value to maximize savings. This stage the combination of customers is made into the vehicle distribution route.

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. Start with any node as the start of the path.
- b. Find the node closest to the last node added to the path.
- c. Then, merge the first and last nodes.

The steps for using the saving matrix method are as follows:

- a. The point starts from the stop point agent, then proceeds to the nearest customer that has not been visited from the starting point of the location.
- b. Then the customer with the closest distance from the previous customer is selected and the vehicle capacity can fulfill the number of deliveries.
 - Customers who are selected as the next distribution destination and there are still vehicle loads left, the step is returned to step (2).
 - If the vehicle has no remaining load capacity, then the step is returned to step (1).
 - If the vehicle load exceeds the carrying capacity and there is no selected location, then the step is returned to step (1). Then it starts again from the depot point and continues with distribution to customers with the closest distance that has not been visited.
- c. The algorithm ends when all customers have been visited once.

5. Determining CO2 emissions

The steps taken after determining the optimal route are calculating CO2 emissions resulting from the newspaper distribution process at XYZ Ltd. Surakarta. 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:

$$\text{Greenhouse Gas Emissions (Kg/Year)} = KE \times FE \times NK \dots\dots\dots(3)$$

Description:

KE = Energy Consumption (TJ/Year)

FE = Emission Factor (TJ/lt)

NK = Calorific Value (kg/TJ)

4. Data Collection

In this study using data from XYZ Ltd. Surakarta in 2018. The use of distance data between agents and the number of requests is carried out for reference to initial data with a carrying capacity of 200 newspaper prints, this data is obtained from previous research. XYZ Ltd. Surakarta has 10 permanent agents with total requests starting from 115 requests to 625 requests which are shown in table 1. Newspaper distribution lasts for 3 hours starting at 03.00 AM and ending at 6.00 AM. The location distance between the warehouse and the agent is shown in Figure 3. In determining the route, the average vehicle speed level during the distribution schedule is shown in Table 2, Table 3, and Table 4. The following is a table of agent lists, number of requests and agent addresses. The following is a table of agent lists, number of requests and agent addresses:

Table 1. List of Agents, Addresses and Number of Requests

No	Code	Agent Names	Address	Request (Prints)
1	A1	TB Sun	Keprabon	625
2	A2	Surya 1 Agency Solo	Keprabon	190
3	A3	ABC Agency	Keprabon	294
4	A4	Revelation Agency	Keprabon	350
5	A5	Mandira/Kencana Agency	Laweyan	280

6	A6	ABA Agency	Timuran	122
7	A7	Sheva Agency	Nonongan	587
8	A8	Specter1 Agency	Cemari	115
9	A9	Asih Agency	Cemari	115
10	A10	Margono 2 Agency	Laweyan	315

The following is a picture of distance between warehouse and each agent:

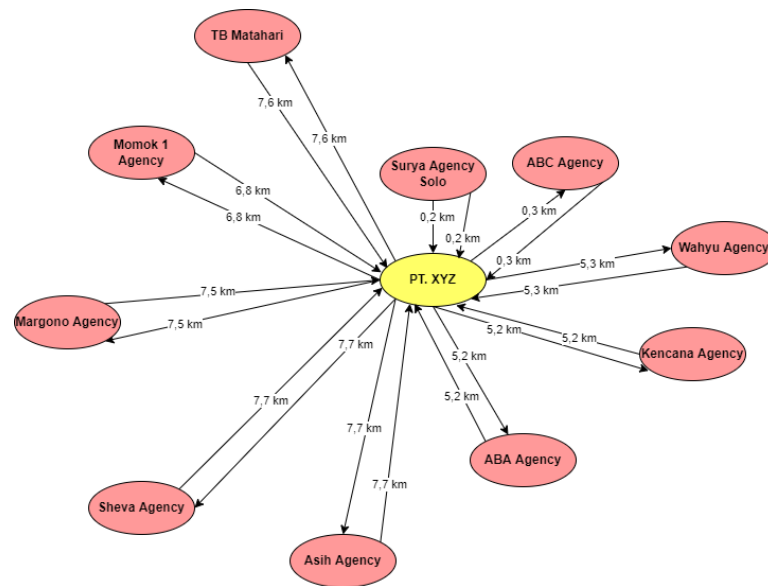


Figure 3. Warehouse Distance with Agents

The following is a table of vehicle volumes according to the time of newspaper delivery:

Table 2. Average Vehicle Speed Level 03.00 AM – 04.00 AM

From	To	Distance (km)	Average Vehicle Speed (km/hour)
Warehouse	A1	7.6	42
	A2	0.2	41
	A3	0.3	45
	A4	5.3	43
	A5	5.1	43
	A6	5.1	47
	A7	7.7	50
	A8	6.8	46
	A9	7.7	51
	A10	7.5	47
Total Average Vehicle Speed (KM/Hour)			45.40

Table 3. Average Vehicle Speed Level 04.00 AM – 05.00 AM

From	To	Distance (km)	Average Vehicle Speed (km/hour)
Warehouse	A1	7.6	40
	A2	0.2	41

From	To	Distance (km)	Average Vehicle Speed (km/hour)
	A3	0.3	45
	A4	5.3	43
	A5	5.1	42
	A6	5.1	46
	A7	7.7	47
	A8	6.8	44
	A9	7.7	47
	A10	7.5	48
Total Average Vehicle Speed (km/hour)			44.30

Table 4. Average Vehicle Speed Level 05.00 AM – 06.00 AM

From	To	Distance (km)	Average Vehicle Speed (km/hour)
Warehouse	A1	7.6	40
	A2	0.2	38
	A3	0.3	37
	A4	5.3	42
	A5	5.1	40
	A6	5.1	38
	A7	7.7	41
	A8	6.8	41
	A9	7.7	40
	A10	7.5	42
Total Average Vehicle Speed (km/hour)			39.90

In distributing the company will incur operational costs, the company uses the services of a third party which monthly vehicle rental fee for each vehicle and its fuel is IDR 650,000.00.

5. Results and Discussion

In this study, the first step is identify using distance matrix. The following is the distance data between the warehouse and the agent:

Table 5. Distance between Warehouse and Agents

	Warehouse	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	7.6	0									
A2	0.2	7.7	0								
A3	0.3	7.7	0.1	0							
A4	5.3	3.6	5.1	5.5	0						
A5	5.1	3.3	5.7	5.6	0.2	0					
A6	5.1	3.3	5.7	5.6	0.2	0.1	0				
A7	7.7	0.2	6.9	6.8	2.8	2.8	2.4	0			
A8	6.8	1.7	6.5	6.4	2.8	2.8	2.4	0.8	0		
A9	7.7	0.4	8.8	8.7	4.7	4.7	4.3	0.5	2.8	0	

	Warehouse	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A10	7.5	1.9	7.7	7.6	3.6	3.6	3.2	1.1	0.9	0.9	0

Based on the data in table 5, the next step is to identify using the saving matrix method. In this case, it is assumed that the distribution of newspapers to each agent is carried out using one truck exclusively. From this it will produce ten different routes with one destination. The following is a saving matrix calculation of the distance from the warehouse from agent one to agent three:

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

$$S(x, y) = 7,6 + 0,3 - 7,7$$

$$S(x, y) = 0,2 \text{ km}$$

So that the results of calculations using the saving matrix are obtained, the distance between warehouse one and warehouse three is 0.2 km.

By using a similar formulation, the results of the calculation with the saving matrix are as follows:

Table 6. Saving Matrix Calculation Results

	Warehouse	A 1	A 2	A 3	A 4	A 5	A 6	A 7	A 8	A 9	A 10
A 1	7.6	0									
A 2	0.2	0.1	0								
A 3	0.3	0.2	0.4	0							
A 4	5.3	9.3	0.4	0.6	0						
A 5	5.1	9.4	-0.4	-0.2	10.2	0					
A 6	5.1	9.4	-0.4	-0.2	10.2	10.1	0				
A 7	7.7	15.1	1	1.2	10.2	10	10.4	0			
A 8	6.8	12.7	0.5	0.7	9.3	9.1	9.5	13.7	0		
A 9	7.7	14.9	-0.9	-0.7	8.3	8.1	8.5	14.9	11.7	0	
A10	7.5	13.2	0	0.2	9.2	9	9.4	14.1	13.4	14.3	

Based on the results of the table 6, by considering the vehicle capacity limit and the initial assumption of 10 different routes, the next step is to make a combination of agents into the vehicle travel route. The combination is made by calculating the allocation of agents with distribution routes. From this combination, the distribution route allocation is known.

Table 7. Distribution Route Allocation

Route	Agent Allocation	Total Newspaper
1	A 8 → A 9 → A 10 → A 1 → A 7	1757 prints
2	A 2 → A 3 → A 4 → A 5 → A 6	1236 prints

Based on the table 7, the next step is to determine the distribution of the agent's newspaper using the nearest neighbor method. Nearest Neighbor was chosen because this method adds the closest agent to complete the route. At each step, the route is built by adding the agent closest to the last point visited by the vehicle until all agents are visited, besides that the iteration is shorter so that it gives the optimum value for solving the combinatorial optimization problem. Then it is assumed that the distribution route takes the warehouse - agent - warehouse route. The results of the

distribution route using the nearest neighbor method are shown in table 8. Route one and route two will then be formed using Google Maps.

Table 8. Route Results and Delivery Orders Based on the Nearest Neighbor Method

Route	Newspaper Distribution Route	Total Distance
1	Warehouse - A 8 – A 7 – A 9 – A 1 – A 10 - Warehouse	17.8 km
2	Warehouse - A 2 - A3 - A4 - A5 - A6 - Warehouse	10.8 km

From the results of calculations using the nearest neighbor method to produce the optimal total distance, route 1 covers a minimum distance of 17.8 KM and route 2 covers a minimum distance of 10.8 KM. Taking into account the level of vehicle volume during distribution, this route can be applied as long as there is no change of agent. The second minimum distance can then produce the time traveled. Based on the average vehicle speed data, it can be assumed that the average truck speed during distribution is 43 km/hour and the stopping time for loading/ unloading newspapers at each agent is 5 minutes.

The following is one calculation of travel time:

$$t1 = \frac{S1}{V}$$

$$t1 = \frac{17,8}{43}$$

$$t1 = 41 \text{ minutes}$$

$$t1 = 41 \text{ minutes} + (5 \times 5)$$

$$t1 = 66 \text{ minutes}$$

So that the results of the calculation of the travel time on the first route are 66 minutes and the travel time on the second route is 49 minutes.

The following is an image of determining distribution route 1 and distribution route 2 using Google Maps:

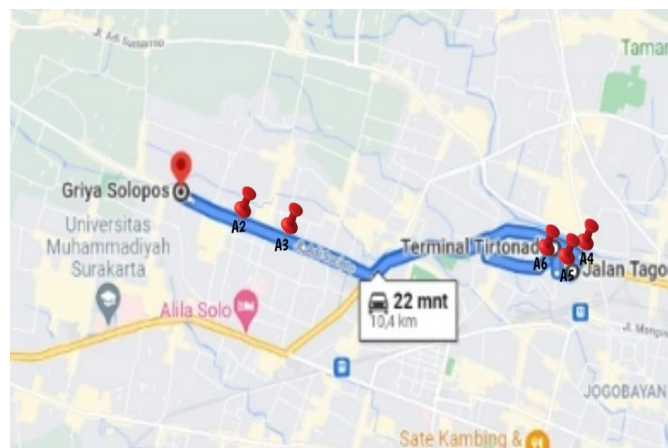


Figure 4. Route 1 with Google Maps

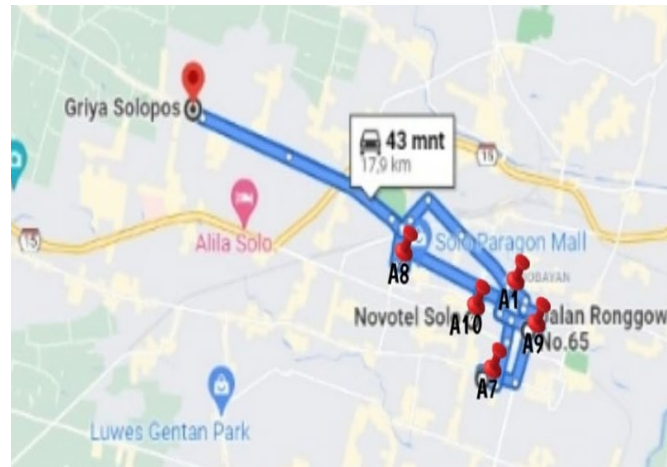


Figure 5. Route 2 with Google Maps

Based on figure 4 and figure 5, the next step is to calculate emissions CO₂ generated from the newspaper distribution process. In this case, it is assumed that the energy consumption in a year is 1044 liters, the type of fuel used is gasoline in the form of Pertamina. CO₂ emission factor data and calorific value are shown in Table 9 and Table 10 as follows:

Table 9. CO₂ Emission Factor Value

Fuel Type	Value (kg/MJ)	Density (kg/m ³)
Gas Oil	741 10 ⁻⁴	837.5
Gasoline	693 10 ⁻⁴	760

Table 10. Fuel Calorific Value

Fuel	Calorie Value	Use
Solar	36 x MJ/Liter	Motor Vehicles, Power Supply
Pertamax/Pertamax Plus	33 x MJ/Liter	Motor Vehicle
Diesel Oil	38 x MJ/Liter	Boilers Industry and Power Supply

Based on the table data, the following is the calculation of CO₂ emissions in the newspaper distribution process:

$$\text{Emission CO}_2 = \text{KE} \times \text{FE} \times \text{NK}$$

$$\text{Emission CO}_2 = 1044 \times 33 \times 693 \times 10^{-4}$$

$$\text{Emission CO}_2 = 2,3875 \times 10^3 \text{ kg CO}_2/\text{year}$$

Based on the calculations and the resulting data, emissions CO₂ produced by XYZ Ltd. Surakarta is 2,3875 x 10³ kg CO₂/year. The last step is to compare the costs incurred by the company. In this case, it is assumed that 1 liter of fuel can cover a distance of 10 km, and 1 liter of Pertamina fuel costs IDR10,400.00. So the company only needs to spend IDR 29,744.00 for each newspaper distribution or IDR 892,320.00 per month. Each stop at the agency is assumed to have the vehicle engine turned off, so that the cost of gasoline that is calculated is only the cost during the trip. By calculating the total mileage, it takes 1.91 hours per delivery, in other words the company can save 1.09 hours per day or 31.9 hours per month.

6. Conclusions

Based on calculations using the saving matrix and the nearest neighbor method, total travel time to all agents is 1 hour 51 minutes, with this travel time the company can save 31.9 hours per month. Taking into account the average vehicle speed data, it is recommended to start distributing it at 03.00 WIB. In addition, with the optimal total mileage obtained, the company produces $2,3875 \times 10^3$ kg CO₂ emissions in a year and only spend IDR 29,744.00 per day for gasoline costs, where the emission results and operating costs are quite low.

In this study using a qualitative settlement method, the data used are long enough so that data updates are needed, especially on agent data, speed data or vehicle density data. In addition, this study only considers CO₂ emissions factor because the limitation of data due to pandemic situation, only considers economic and environmental factors by calculating fuel consumption, has not considered social factors and has not calculated the value of electricity consumption. Suggestions for future research would be better if taking data directly from the Solo Police in order to obtain accurate data on traffic density levels and can also consider to other emission factor, social factors and calculate the value of electricity consumption so that companies can apply the concept of sustainable supply chain management.

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