Determination of Routes for Daily Newspaper Product Distribution with Saving Matrix Methods

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Abstract. The newspaper industry has several distinctive characteristics that make it stand out from other industries due to tight production and delivery times. The results of a case study in one of the newspaper companies in the city of Surakarta, found several problems, one of which is the slow distribution process due to the determination of the wrong route. The problem of distribution is the problem of the Vehicle Routing Problem (VRP). Vehicle Routing Problem is a problem related to determining the optimal distribution route by involving several obstacles to serve a number of agents at the request of each agent. One of the obstacles of the Vehicle Routing Problem is the capacity of the vehicle. This study applies the Vehicle Routing Problem using the Nearest Neighbor method to optimize the distribution route. The Nearest Neighbor method is used to design routes based on the next closest distance. Distribution efficiency is evaluated based on the total distance, time and load borne by the vehicle fleet. The results showed that the distribution route was divided into two routes with a total distance traveled as far as 27.3 km and a total time of 1 hour 30 minutes in accordance with the time windows policy that is applied daily Solopos. Based on the use of these methods, it can save company expenses of Rp. 134,160.00 per day or Rp. 1,609,920.00 per month in product distribution for the Surakarta City area.

1. Introduction
The globalization and free trade era have erased the regional border in the trading system, resulting in a sharply increasing competition in the business sector. The easy access of information provided by various media causes the competition in business sector to improve. One example of the media is newspaper [Basriati, 2015]. The newspaper industry has several distinctive characteristics that make it stand out from other industries. The tight delivery time makes it impossible to save the inventories in a very short time for production and distribution. On one hand, there are pressures from the newsroom to foster the production process as late as possible to input last minute news, and on the other hand there are also pressures from the production and distribution departments to begin the production as early as possible [Furnes, 2014]. The supply chain of newspaper industries mostly consists of content editing, manufacture, and distribution. The manufacture comprises of pre-press, printing, and packing. While the distribution consists of delivery to distribution centers, drop-off points or retailers and customers [Furnes, 2014].

Generally, the production and distribution problems in the paper supply chain are the production planning integration and distribution to minimize the total costs [Aqidawati, Sutopo & Hisjam, 2018].
Companies have their own distribution deadlines. In this case, transportation plays an important role in the supply chain. Even though there are suppliers who conduct delivery in the same market area, coordination between two or more suppliers is seldom to happen [Intan, Sutopo & Hisjam, 2017]. There is a research that can build a model to optimize the profits of supply chain by including uncertainty in supply chain negotiations, transportation problems, and planning of product allocation from suppliers to buyers by taking into account the time value of money (TVM) [Sutopo, Erliza & Heryansyah, 2016]. Most daily newspapers are published in the morning, evening newspapers were once quite common but now they are hard to find. It is common for newspapers to guarantee the delivery of daily newspapers before 06.00, and fulfilling the delivery deadlines is very important. As a result of time pressure, most of the production and distribution are carried out at night and often done in a short time [P3L, 2006].

The case study results in a newspaper company in Surakarta city illustrate some problems, one of which is the slow distribution process due to the incorrect route determination [Saputra, Sutopo & Hisjam, 2020]. Location and routing are very complex problems. The most important reason is that there are many alternative location models combined with a large number of routing models. Another reason is that different horizontal planning for location, routing decisions, and the fact that location problems are in contrast to routing problems require request aggregation [Klose & Drexl, 2005]. The distribution problem is caused by a Vehicle Routing Problem (VRP) problem. It is the problem of finding a route with minimum cost from a depot to customers with a number of different requests [Amri, Rahman & Yuniarti, 2014].

In order to solve the VRP problem, this research utilizes saving matrix method to minimize the cost as well as the transportation time. In addition, nearest neighbor method is used to determine the delivery routes. Other researchers have developed the VRP problem solving, for example the integer programming (Kulkarni and Bhave, 1985), mixed integer programming (Longo and Aragao, 2004), tabu search (Fermin and Roberto, 2004), genetic algorithm (Baker and Ayechew, 2003), simulated annealing (Tavakkoli, 2005), ant colony (Bell and McMullen, 2004), etc. Utilizing the exact optimization approach such as integer programming will take a long computation time, especially for large problems (if there are a large number of points served). Therefore, the authors choose the heuristic approach through the algorithm which is used to provide the optimum solution by learning, so it is faster than the exact optimization approach. Furthermore, one oftenly-used heuristic approach is the saving matrix. It is a method that minimize the route taken by considering the existing obstacles. In the initial case at PDAM Bandarmasih, it is proven that the saving matrix method can minimize time and transportation costs [Darmawan, 2011]. The saving matrix method is able to provide results regarding the fleet deployment based on their capacity load in a number of delivery areas based on the biggest savings [Ikfan & Masudin, 2013].

This article aims to solve the problems of route determination in the newspaper company in Surakarta city so the time and cost minimization as well as the best delivery route can be obtained.

2. Research Method

One classification of route-determining and scheduling problems is the Vehicle Routing Problem (VRP). The VRP problem is an integer programming problem, where a set of routes for a vehicle fleet sourced coming from one or several depots should be determined to serve the geographically-dispersed customers (www.neo.lcc.uma.es; Marinakis, 2012). The purpose of VRP is to deliver the product to a group of customers whose demand whose demands are already known by spending a minimum cost, also starting and ending at one or more depots. The output of this problem is a low cost and feasible route for each vehicle (the route is a sequence of locations that must be visited with an indication of requiring service). One interesting problem in the discussion of Vehicle Routing Problem is the Capacitated Vehicle Routing Problem (CVRP). CVRP is a case of determining the route of a K vehicle that aims to minimize the total distance covered by all routes, which will meet the capacity of vehicle Q and serve each customer. The following constraints will exist:

a. Each route will start and end at one depot.

b. Each customer will only be visited by one vehicle.
c. The total demand for each route cannot exceed the capacity of vehicle Q.

The CVRP formulations (Fukusawa, 4), are:

a. Purpose Function

\[
\min \sum_{e \in E} C_e x_e
\]

b. Constraint Function

\[
\sum_{e \in \delta((i))} x_e = 2 \quad \forall i \in V +
\]

\[
\sum_{e \in \delta(\{0\})} x_e = 2K
\]

\[
\sum_{e \in \delta(S)} x_e \geq 2k(S), \quad \forall S \in V +
\]

\[
x_{ij} \in \{0,1\}, \forall \{i,j\} \in E
\]

Note:

- \( V \): set node,
- \( E \): set edge / arc,
- \( V' / V^+ \): \{1...n\} set node of customer,
- \( N \): customer,
- \( c_e \): non negative values in each arc \( \{i,j\} \in \delta \), can be the cost, distance or time, which are assumed to be symmetrical, where \( c_{ij} = c_{ji} \),
- \( x_e \): the number of vehicles passing through the arc \( \{i,j\} \in E \), is equal to 0 if not passed by the vehicle and is equal to 1 if passed by the vehicles
- \( \forall \): all,
- \( K \): number of vehicles,
- \( \delta(S) \): cut set defined in S,
- \( S \): \( \{S \subseteq V', S \geq 2\} \),
- \( k(S) \): the minimum number of vehicles with Q capacity needed to fulfill customers’ demand in S, the value is \( \{d(S)/Q\} \),
- \( d(S) \): indication of the total node requests in the subset \( S \subseteq V' \), where \( q(S) = \sum_{i \in S} q_i \),
- \( Q \): vehicle capacity,
- \( q_i \): non negative demand on \( V' \), where each \( V' \) vertex has non negative demand \( q_i \) on condition of \( 0 < q_i \leq Q \).

Saving Matrix method is used to determine the product’s distribution route in the marketing area by determining the distribution route to be travelled and the number of vehicles based on the capacity of the vehicles in order to obtain the shortest route and minimum transportation costs. There are steps or several algorithms that should be taken in the matrix saving method. Below are the steps to complete the Saving Matrix method:
Step 1: Determining the distance matrix

The distance matrix states the distance between each pair of customers that should be visited. The distance can be determined utilizing google earth application, google maps, or manual calculation with the speedometer on the vehicle used. Vo Vi Vj Vn C0i

|     | Vo  | Vi  | Vj  | Vn  | C0i |
|-----|-----|-----|-----|-----|-----|
| Vo  | 0   |     |     |     |     |
| Vi  |     | 0   |     |     |     |
| Vj  |     |     | 0   |     |     |
| Vn  |     |     |     | 0   |     |

Step 2: Determining the saving matrix

The savings matrix shows the savings that occur when two customers are combined. If S(x, y) states the distance saved, for example the trip from the center or starting point in a route by distance from depot to customer 1 and from customer 1 back to depot plus the distance from depot to customer 2 and then back to depot) subtracted by (distance from depot to customer 1 to customer 2 plus distance from customer 2 to depot), then the equation to find the amount of savings is:

|     | Vo  | Vi  | Vj  | Vn  | Cin |
|-----|-----|-----|-----|-----|-----|
| Vo  | -   |     |     |     |     |
| Vi  |     | -   |     |     |     |
| Vj  |     |     | -   |     |     |
| Vn  |     |     |     | -   |     |

Step 3: Combining customers into vehicle travel routes

In this step, the customers are divided into a vehicle travel route by considering the customers and the vehicle capacity used. A route is considered feasible if the total number of requests from all customers does not exceed the capacity of the vehicle and the number of requests from one customer can be accommodated by one vehicle. The procedure used for grouping the customers is based on the largest savings matrix value. So, the first thing to do is sorting the largest saving matrix value until the capacity of the vehicle used can accommodate all demands. If the maximum capacity is reached, the procedure will be repeated until all customers are allocated in a route.

Step 4: Determining the order of customers

The order of customers is determined using farthest insert, nearest insert, Nearest Neighbor, Greedy, and Sweep procedures. The procedure which has the least distance result will be chosen.

- Farthest Insert Method
  This method starts from the farthest customers and continued by putting other customers to the route that has the biggest mileage increase using the following formula:
• Nearest Insert Method
  Beginning from the depot, this method adds the closest customers to complete the route. After there is no more closest customer to other customers, the last point visited by the vehicle will be inserted until all customers are visited.

• Nearest Neighbor Method
  Starting from the depot, this method adds the closest customers to complete the route. At each step, the route is built by adding the customers closest to the last point visited by the vehicle until all consumers are visited.

• Greedy Method
  This method is one type of algorithm which uses a problem solving approach by finding a temporary maximum value in each step or the local maximum. Greedy algorithms usually provide solutions that are close to the optimum value in a fairly quick time.

• Sweep Method
  The principle used in the sweep method is to divide refugee posts into several clusters and then optimize the routes for each cluster.
  First, all the vehicles are empty. Then, beginning with the first vehicle, this method inserts the unvisited nearest customers (Nearest Neighbour) into the route one by one. During the customer insertion process, the vehicle may not exceed its maximum capacity. Then the same process is carried out for the next vehicles, until all vehicles are full or all customers are visited.
  The algorithm advantage of Nearest Neighbor is that it has shorter iteration which gives optimum result to solve the combinatorial optimization problems. Therefore some trips that use the Nearest Neighbor method can be used as an initial route that can make improvements for other methods.
  The algorithm lack of Nearest Neighbor is when the point is more than 20, then the calculation will need quite a long time so it tries to find a way to get good, but not the best results. However, some cities that are not too far away can be travel and then visited at the end which results in further distance and more expensive costs.
  The steps of the Nearest Neighbor method are as follows:
  Step 1
  Starting from the depot, then look for unvisited customers who have the shortest distance from the depot as the first location.
  Step 2
  Other customers who have the closest distance to the previously selected customer and the delivery number does not exceed the vehicle’s capacity.
  a. If there is a customer selected as the next customer and there is remaining vehicle capacity, return to step (2).
  b. If the vehicle has no remaining capacity, return to step (1).
  c. If no location is selected because the number of delivery exceeds the capacity of the vehicle, return to step (1). It starts again from the depot and visits unvisited customers who have the closest distance.
  Step 3
  If all customers have been visited exactly once then the algorithm ends

3. Result and Discussion

Previous researches are one of the authors’ references in conducting research so that the author can enrich the theories used. From the previous researches, the authors do not find research with the same title as the authors’ research title. However, the authors put forward some research as references to enrich the study material in the authors’ research. Below are the previous researches in the form of journals related to the research conducted by the authors.


Table 3. Previous Research

| Name of Researcher | Research Title                                                                 | Research Results                                                                                                                                 |
|--------------------|--------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| Rahmawati, Nazaruddin, & Sari, 2014. | Usulan Model dalam Menentukan Rute Distribusi untuk Meminimalkan Biaya Transportasi dengan Metode Saving Matrix di PT. XYZ | The sub formation in the proposed route using the saving matrix method produces fewer sub routes than the distribution route applied by the company, where there are 7 proposed sub routes and there are 14 sub routes used by the company. The savings matrix can save a distribution cost of IDR 309,725,- |

Difference: besides using the number of requests variable, transportation cost variable, and distance variable, Rahmawati, Nazaruddin and Sari’s research used the capacity variable for each vehicle. Meanwhile, the variables used by the authors of this research are number of requests, coordinates of distribution points, distances between warehouses & agents, vehicle rental costs variables.

| Name of Researcher | Research Title                                                                 | Research Results                                                                                                                                 |
|--------------------|--------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| Sodikin, 2014.     | Penentuan Rute Distribusi Produk yang Optimal dengan Memperhatikan Faktor Kecepatan Kendaraan guna Meningkatkan Efisiensi Penggunaan BBM | The initial distance is 1092.4 km. After saving matrix is used by considering factors of vehicle’s speed, the distance travelled for product distribution reduces to 454.2 km. 638.2 km of distance can be saved in route 1. The effectiveness obtained through the use of saving matrix method by considering the vehicle speed is 58.42%. The fuel cost saved is IDR 400,717,- or distribution cost efficiency of 57.45%. |

Difference: the research carried out by Sodikin (2014) focused on determining the optimal product distribution route by considering the vehicle’s speed factor based on the distance from the warehouse to the retailer and the distance between retailers in order to improve fuel efficiency.

| Name of Researcher | Research Title                                                                 | Research Results                                                                                                                                 |
|--------------------|--------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| Indrawati, 2014.   | Penentuan Rute Distribusi Produk yang Meminimunkan Jarak Tempuh dan Jumlah Kendaraan dengan Pendekatan Metode Heuristik Vehicle Routing Problem | The product distribution problem modeled in VRPTW can provide a sequence that has taken into account the obstacles such as time and vehicle capacity. By knowing the total distance, the Mantab Rasa SME can consider implementing the route obtained from the data processing. Reducing the number of vehicles used from 3 type B vehicles to only 2 vehicles can save 1 type B vehicle. |
Difference: the research conducted by Indrawati (2014) utilized nearest to depot method to determine the distribution route. Meanwhile, the authors of this research use farthest insert, nearest insert, nearest neighbor, greedy, and sweep methods to determine the route.

In this research, observation of the daily distribution of Solopos in May 2018 was conducted. The initial data used is the distance between agents and the number of requests for each agent shown in Table 3 with a transport car that has the capacity of 2000 copies of newspaper. The company has 10 permanent agents with various daily demands for each agent ranging from 115 to 625 in May 2018. The everyday distribution of Solopos newspaper begins at 3:00 a.m. and ends at 6:00 a.m. with a service duration of 1 minute for 50 copies of newspaper. The coordinates of each agent can be determined using Google Maps as shown in Table 5.

### TABLE 4. List of Agents, Addresses & Number of Demands

| No. | Code | Name of Agent                      | Address | Demand (copies) |
|-----|------|------------------------------------|---------|-----------------|
| 1   | A1   | TB Matahari                        | Keprabon| 625             |
| 2   | A2   | Surya 1 Agency Solo                | Keprabon| 190             |
| 3   | A3   | ABC Agency                         | Keprabon| 294             |
| 4   | A4   | Wahyu Agency                       | Keprabon| 350             |
| 5   | A5   | Mandira/Kencana Agency             | Laweyan | 280             |
| 6   | A6   | ABA Agency                         | Timuran | 122             |
| 7   | A7   | Sheva Agency                       | Nonongan| 587             |
| 8   | A8   | Momok1 Agency                      | Cemari  | 115             |
| 9   | A9   | Asih Agency                        | Cemari  | 115             |
| 10  | A10  | Margono 2 Agency                   | Laweyan | 315             |
|     |      | **TOTAL**                          |         | **2993**        |

### TABLE 5. Information of Distribution Point Coordinate

| No. | Code | X Coordinate | Y Coordinate | Demand (copies) |
|-----|------|--------------|--------------|-----------------|
| 1   | A1   | -7.569067    | 110.824795   | 625             |
| 2   | A2   | -7.545586    | 110.779160   | 190             |
| 3   | A3   | -7.545586    | 110.779160   | 294             |
| 4   | A4   | -7.550793    | 110.817880   | 350             |
| 5   | A5   | -7.553314    | 110.820476   | 280             |
| 6   | A6   | -7.553469    | 110.820597   | 122             |
| 7   | A7   | -7.568512    | 110.823682   | 587             |
| 8   | A8   | -7.567927    | 110.817130   | 115             |
| 9   | A9   | -7.572134    | 110.823997   | 115             |
| 10  | A10  | -7.573876    | 110.818691   | 315             |

The company spends operational costs that comprise of vehicle operating costs and fuel costs. Since the company uses third party services, the company only needs to pay a vehicle rental fee of Rp 650,000.00 per month for each vehicle and also the fuel costs.
The saving matrix method is used to minimize the route. The method can form a route and sequence of stop points in one route. The initial step taken is identifying the distance matrix between warehouse to each agent and the distance between stores by using the coordinates presented in Table 5.

| TABLE 6. Distance Between Warehouse and Agent |
|------------------|---|---|---|---|---|---|---|---|---|
| Warehouse | A1  | A2  | A3  | A4  | A5  | A6  | A7  | A8  | A9  |
| A1        | 7.6 | 0.0 |     |     |     |     |     |     |     |
| A2        | 0.2 | 7.7 | 0.0 |     |     |     |     |     |     |
| A3        | 0.3 | 7.7 | 0.1 | 0.0 |     |     |     |     |     |
| A4        | 5.3 | 3.6 | 5.1 | 5.5 | 0.0 |     |     |     |     |
| A5        | 5.1 | 3.3 | 5.7 | 5.6 | 0.2 | 0.0 |     |     |     |
| A6        | 5.1 | 3.3 | 5.7 | 5.6 | 0.2 | 0.1 | 0.0 |     |     |
| A7        | 7.7 | 0.2 | 6.9 | 6.8 | 2.8 | 2.8 | 2.4 | 0.0 |     |
| A8        | 6.8 | 1.7 | 6.5 | 6.4 | 2.8 | 2.8 | 2.4 | 0.8 | 0.0 |
| A9        | 7.7 | 0.4 | 8.8 | 8.7 | 4.7 | 4.7 | 4.3 | 0.5 | 2.8 |
| A10       | 7.5 | 1.9 | 7.7 | 7.6 | 3.6 | 3.6 | 3.2 | 1.1 | 0.9 |
|           | 0   |     |     |     |     |     |     | 0.9 | 0.0 |

The next step is identifying the savings matrix assuming that each agent will be visited by one truck exclusively. In other words, there will be 10 different routes with one destination each. The following example shows the calculation of the distance saving from warehouse to store 1 to store 2.

\[
S(x, y) = J(G, x) + J(G, y) - J(x, y)
\]

\[
S(x, y) = 7.6 + 0.2 - 7.7
\]

\[
= 0.1 \text{km}
\]

So, the distance saving from store 1 to store 2 is 0.1 km. By using the same formula, the saving results are as follows:

| TABLE 7. Results of Distance Savings Calculation |
|------------------|---|---|---|---|---|---|---|---|---|
| Warehouse | A1  | A2  | A3  | A4  | A5  | A6  | A7  | A8  | A9  |
| A1        | 7.6 | 0.0 |     |     |     |     |     |     |     |
| A2        | 0.2 | 1.0 | 0.0 |     |     |     |     |     |     |
| A3        | 0.3 | 0.2 | 0.4 | 0.0 |     |     |     |     |     |
| A4        | 5.3 | 9.3 | 0.4 | 0.6 | 0.0 |     |     |     |     |
| A5        | 5.1 | 9.4 | -0.4| -0.2| 10.2| 0.0 |     |     |     |
| A6        | 5.1 | 9.4 | -0.4| -0.2| 10.2| 10.1| 0.0 |     |     |
| A7        | 7.7 | 15.1| 1.0 | 1.2 | 10.2| 10.0| 10.4| 0.0 |     |
| A8        | 6.8 | 12.7| 0.5 | 0.7 | 9.3 | 9.1 | 9.5 | 13.7| 0.0 |
| A9        | 7.7 | 14.9| -0.9| -0.7| 8.3 | 8.1 | 8.5 | 14.9| 11.7|
| A10       | 7.5 | 13.2| 0.0 | 0.2 | 9.2 | 9.0 | 9.4 | 14.1| 13.4|
|           | 0   |     | 13.2| 0.0 | 9.2 | 9.0 | 9.4 | 14.1| 14.3|
|           |     |     |     |     |     |     |     | 14.1| 14.3|
|           |     |     |     |     |     |     |     | 14.1| 14.3|
|           |     |     |     |     |     |     |     | 14.1| 14.3|
|           |     |     |     |     |     |     |     | 14.1| 14.3|

Based on the distance saving calculation, the next step is allocating the agent to the vehicle or route with the initial assumption of 10 different routes. However, the agents allocation can be combined with the limit of existing vehicles’ capacity. The combination starts from the largest savings in order to maximize savings.

Based on calculations in allocating stores into the routes or vehicles, the results of calculation of store allocation into the route or delivery vehicle are known to be carried out with 2 shipping routes:

Route 1: Agent 8, Agent 9, Agent 10, Agent 1, and Agent 7 (load 1757 copies)
Route 2: Agent 2, Agent 3, Agent 4, Agent 5, and Agent 6 (load 1236 copies)

After the route allocation is made, the next step is determining the order of delivery by using Farthest Insert, Nearest Insert, Nearest Neighbour, Greedy, and Sweep methods. It is done because the agents in the route group are still random so they need to be sorted. It is assumed that each agent travel the route of Warehouse-Agent-Warehouse, then the delivery is sorted based on the method and the route as seen in Table 8. Then, route 1 and 2 are formed with the help of google maps. Finally, the Solopos distribution route is made, as seen in table 7.

**TABLE 8. Recapitulation of Distance and Delivery Order Based on Method**

| Route   | Order of Delivery                                      | Method       | Total Distance (km) |
|---------|--------------------------------------------------------|--------------|---------------------|
| Route 1 | Warehouse – A7 – A8 – A9 – A10 – A1 – Warehouse       | Farthest Insert | 17.06               |
|         | Warehouse – A8 – A7 – A9 – A1 – A10 – Warehouse       | Nearest Insert | 17.08               |
|         | Warehouse – A8 – A7 – A9 – A1 – A10 – Warehouse       | Nearest Neighbour | 17.08               |
|         | Warehouse – A8 – A7 – A1 – A9 – A10 – Warehouse       | Greedy       | 16.06               |
|         | Warehouse – A8 – A1 – A7 – A9 – A10 – Warehouse       | Sweep        | 17.06               |
|         | Warehouse – A4 – A5 – A6 – A3 – A2 – Warehouse        | Farthest Insert | 11.04               |
|         | Warehouse – A2 – A3 – A4 – A5 – A6 – Warehouse        | Nearest Insert | 10.07               |
|         | Warehouse – A2 – A3 – A4 – A5 – A6 – Warehouse        | Nearest Neighbour | 10.07               |
|         | Warehouse – A2 – A3 – A4 – A5 – A6 – Warehouse        | Greedy       | 10.07               |
|         | Warehouse – A3 – A2 – A4 – A5 – A6 – Warehouse        | Sweep        | 10.09               |

From the calculation by using Farthest Insert, Nearest Insert, Nearest Neighbour, Greedy, and Sweep result in minimum total distance. Based on table 8, route 1 have a total distance of 16.6 km from the Greedy calculation method. Route 2 have a minimum distance of 10.7 km based on Nearest Insert, Nearest Neighbour, and Greedy methods. So, the order of distances selected by the method is presented in Table 9 below. The route can be applied provided that there are no changes to agents or current traffic signs. In addition, the results obtained only cover the area of Surakarta city.

**TABLE 9. Recapitulation of Distribution Route Distance**

| Route   | Order of Delivery                                      | Total | Distance | Time       |
|---------|--------------------------------------------------------|-------|----------|------------|
| Route 1 | Warehouse – A8 – A7 – A1 – A9 – A10 – Warehouse       | 1757  | 16.06    | 60 minutes |
| Route 2 | Warehouse – A2 – A3 – A4 – A5 – A6 – Warehouse        | 1236  | 10.07    | 30 minutes |
From the data collected, the next step is calculating the cost by comparing the expenses incurred by the company. Based on the results obtained, the company can save 4.3 km every day. Since the distribution process in this area takes place every day, the company can save a distance of 129 km monthly. Assuming that 1 litre of fuel can cover a distance of 10 km, and 1 litre of Pertamax fuel costs IDR 10,400, then the company can save up to IDR 134,600 each month and IDR 1,609,920 each year. The savings are considered quite large considering that the company does not need to invest.

4. Conclusions
Based on the Vehicle Routing Problem solving with Time Windows using saving matrix method, there are two routes for Solopos distribution optimization. The total travel time of both routes is 1 hour 30 minutes according to the time windows policy implemented by the company. By using
saving matrix method, the company can save up to IDR 134,600 each month and IDR 1,609,920 each year for the product distribution in Surakarta.

This article can be developed by combining qualitative solving methods. In addition, this research still uses distance and operational costs in processing the data. It will be better if future research considers the traffic level and delivery time:

1. Solopos can use the routes provided in this research to reduce the delivery expenses in distributing their product.
2. The final results of processing those methods are not the most optimal results. So, this research can be developed by using other methods of distribution.

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