Implementation of saving matrix to determine distribution route of Kalog Express Surakarta

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Abstract. Transportation is important in the courier services industry. Determination of vehicle routes must be carried out appropriately and optimally for the smooth delivery of these services. This research was conducted in a company engaged in the field of courier services industry. The sample of this study were 12 consumers of door-to-door shipments issued by courier services. Data analysis was performed using the Saving Matrix method by considering the vehicle's transport capacity and time windows. Time windows used are time intervals that indicate the start time of vehicle usage from the distribution center and the time of return of the vehicle to the distribution center. Calculation of distribution costs by using the saving matrix method obtained cost savings of 3-25%.

1. Introduction

In the goods distribution industry requires an appropriate vehicle route determination to ensure the efficiency of the service. A distribution route can be optimized so as to minimize distribution costs. PT KAI Kalog Express is a company engaged in the field of freight forwarding services in which there is one freight forwarder by courier. The volume of courier activities in this company throughout 2017 is 29,387 tons. Realized revenue amounted to IDR 89,729 million or 118% of its target of IDR 76,165 million. This revenue increased 47.49% from the previous year which amounted to IDR 60,839 million so demand is increasing. Demand increases, it is necessary to calculate the minimum distribution costs so that later it can meet demand and have strong competitiveness with other competitors. In this company the shipping costs of an item are more expensive compared to other competitors. So many consumers prefer delivery services in other companies. One of the problems in the courier services industry is the high distribution costs. This distribution cost concerns the distance traveled, the amount of fuel used, labor costs, and time. Distribution can be interpreted as an activity to move and store a product from the supplier stage to the consumer stage in the supply chain [1]. Transportation is part of the economic activity, which is associated with the improvement of people and businesses by changing the geographical location of goods and people [2]. Transportation is one of the key logistics functions.
associated with moving goods vehicle on a particular supply chain technology, operations and functions of logistics, including forwarding, cargo handling, packaging, and ownership of the goods transfer, risk insurance, customs procedures, and so on. And other definition of transportation is the specific modes used to move goods in a distribution network [3]. The problem of scheduling and determining delivery routes can have several goals to be achieved such as the goal to minimize shipping costs, minimize the time, or minimize mileage [4]. Optimal distribution aims to obtain minimum costs so that the level of competitiveness of the company can be increased [5].

In this article, the saving matrix method will be used in optimizing distribution routes. The Savings Matrix Method is a method used to determine the product distribution route to the marketing area by determining the distribution routes that must be passed and the number of vehicles based on vehicle capacity to obtain the shortest route and minimal transportation costs. Matrix Savings Method is also one of the techniques used to schedule a limited number of vehicles from facilities that have maximum capacity [6]. Developed a heuristic solution method which became known as the savings method and was the first algorithm that became widely used [7]. It is called the Clarke-Wright algorithm, after the authors, but in the early years it was also described as the Wright-Fletcher-Clarke algorithm [8] or the Fletcher-Clarke-Wright algorithm [9,10]. A comprehensive chapter on transport planning. There they present a routing and scheduling transportation problem, for a company called Peapod, which they solve with what they call a saving matrix method [11]. They solve the problem in four steps: (1) identify resistance matrix, (2) identify the saving matrix, (3) assign customers to vehicles or routes, and (4) sequence customers within routes. Saving Matrix method is essentially a method to minimize distance or time or cost by considering constraints [12]. This method has the advantages of being easily implemented to solve complex problems [13].

In carrying out its operational activities the problem of route determination and scheduling is a problem that is often faced by the company's transportation operations. The management must decide which vehicle is used to which consumers and which routes each vehicle must pass. Management must also ensure that no vehicle is overloaded and shipping does not exceed the specified time limit. In addition there are also problems regarding route determination by undetermined couriers which causes delays in delivery to consumers. This is caused by many factors, including couriers prioritizing consumers who have orders with more numbers and traffic jams during shipping. This article is intended to solve delivery problems in courier services companies, PT KAI Kolog Express in the city of Surakarta to obtain a minimal distribution cost by considering the vehicle capacity, service time and layout of goods in the vehicle. To determine the distribution route, the distribution of goods in Surakarta Region and is examined by analyzing the number of requests per customer can be known from the company.

2. Method of Research
The research method used in this research is the data collection stage and followed by data processing. The activities of data collection and processing is discussed below.

2.1. Data collection
Data collection methods used are direct observation in the form of data collection and interviews to the freight forwarding industry, for this case study, the PT KAI Kolog branch office is located in the city of Surakarta and then some data will be used in this study, including number of nodes, vehicle number, demand amount, route, delivery time and service time.

2.2. Data processing
Data processing is done by using the Saving Matrix method to find out the optimal cost for delivery services. The Saving Matrix method has 3 steps:
   i.First step:
   Identify the distance matrix, at this stage the data needed is the distance data from the distribution center to each consumer and the distance between consumers. The data is the output data from the
Google Maps Earth software with input in the form of addresses of each consumer and distribution center.

ii. Second step:
Identify Saving Matrix, at this stage the savings will be obtained if there is a merger for delivery to several destinations [14]. The formulation to get the amount of savings can be seen in the following equation:

$$S(x, y) = J(\text{DC}, x) + J(\text{DC}, y) - J(x, y)$$

- $S(x, y)$ = Distance Saving
- $J$ = Distance
- $\text{DC}$ = Distribution Center
- $x$ = First consumer
- $y$ = Second consumer

After obtaining a savings matrix, then sort the results of saving the distance from the largest to the smallest [15]. Through the stages of sequencing the amount of savings is then generated by the sequence of consumers. Determination of the sequence in one route is to use the Nearest Neighbor procedure which is a route made by adding the nearest customer from the last point visited by the vehicle [16]. Iteration starts from DC, then the journey goes to the customer closest to DC, and so on.

iii. Third step:
Allocate consumers to vehicles, at this stage the division of the route is carried out with restrictions in the form of vehicle capacity, service time and vehicle capacity layout. After obtaining travel routes, the next step is to calculate the total cost of all shipping combinations and compare with actual situation.

3. Result and Discussion
From the results of data collection related to shipping services conducted by Kalog Express, the data collected consists of consumer addresses, consumer demand and distribution related costs. The data provided insight into Kalog Express as discussed below. Implementation of the saving matrix method can be done easily by referring to the Standard Operation Procedure (SOP). With this SOP, the company can set distribution route planning based on the selection of distance, vehicle capacity and time window for the courier.

3.1. Identification of Distance Matrix
First, based on consumer data in the form of addresses of each consumer, it can be seen that the distribution of consumers from Kalog Express Surakarta is served by the company's couriers. The pink dot is the office of Kalog Express located in Surakarta which is a distribution center or collection point for goods to be sent to consumers. The following Figure 1 below is the mapping of company's courier consumer distribution.

![Figure 1. The Mapping Of Company’s Courier Consumer Distribution](image-url)
The data needed in the identification of distance matrix is the distance from the distribution center to each consumer and the distance between consumers. Consumer address and the demand of each consumer obtained from the company can be seen in Table 1. For determining the distance, supported by the development of information technology today, there are many online application services that can search a location. One of the online application that can search location is Google Maps [4]. Then the output from Google Maps Earth software shown in Table 2.

### Table 1. Consumers Address

| Cust | Address | Demand (kg) |
|------|---------|-------------|
| 1    | Jl. Rinjani Dalam 4 No.2, Mojosongo, Jebres, Kota Surakarta, Jawa Tengah 57127 | 100 |
| 2    | Jl. Awan No.24, Jebres, Kota Surakarta, Jawa Tengah 57126 | 4 |
| 3    | Jl. RE Martadinata No.15, Sudiroprajan, Jebres, Kota Surakarta, Jawa Tengah 57121 | 8 |
| 4    | Gang Banyuanyar Utara 1, Banyuanyar, Banjarsari, Kota Surakarta, Jawa Tengah 57137 | 25 |
| 5    | Gg. III No.32, Panularan, Laweyan, Kota Surakarta, Jawa Tengah 57149 | 10 |
| 6    | Jl. Babar Layar No.41, Danukusuman, Serengan, Kota Surakarta, Jawa Tengah 57156 | 35 |
| 7    | Jl. Griyan Baru IV No.85, Griyan, Baturan, Colomadu, Kabupaten Karanganyar, Jawa Tengah 57171 | 20 |
| 8    | Jl. Ps. Plumbon, Rw. 4, Gadingan, Mojolaban, Kabupaten Sukoharjo, Jawa Tengah 57554 | 45 |
| 9    | Jl. Mencio Raya No.24, Nilasari, Gonilan, Kartasura, Kabupaten Sukoharjo, Jawa Tengah 57169 | 15 |
| 10   | Jl. Kandang Menjangan, Dusun II, Wironanggan, Gatak, Kabupaten Sukoharjo, Jawa Tengah 57557 | 111 |
| 11   | Jl. Melati 10, Perumnas Ngringo, Ngringo, Jaten, Kabupaten Karanganyar, Jawa Tengah 57731 | 165 |
| 12   | Jl. Veteran Perang Kemerdekaan No.5, Badran, Triyagan, Mojolaban, Kabupaten Sukoharjo, Jawa Tengah 57554 | 93 |

### Table 2. Distance Matrix

| Cust | DC  | Cust 1 | Cust 2 | Cust 3 | Cust 4 | Cust 5 | Cust 6 | Cust 7 | Cust 8 | Cust 9 | Cust 10 | Cust 11 | Cust 12 |
|------|-----|--------|--------|--------|--------|--------|--------|--------|--------|--------|---------|---------|---------|
| Cust 1 | 4.7 | 0      |        |        |        |        |        |        |        |        |         |         |         |
| Cust 2 | 6.2 | 5.3    | 0      |        |        |        |        |        |        |        |         |         |         |
| Cust 3 | 3.9 | 3.8    | 4.8    | 0      |        |        |        |        |        |        |         |         |         |
| Cust 4 | 3.9 | 5.2    | 8.8    | 7.4    | 0      |        |        |        |        |        |         |         |         |
| Cust 5 | 3.7 | 7.7    | 8.6    | 4.3    | 6.9    | 0      |        |        |        |        |         |         |         |
| Cust 6 | 5.8 | 7.9    | 3.3    | 8.6    | 2.9    | 0      |        |        |        |        |         |         |         |
| Cust 7 | 5.9 | 8.4    | 12     | 7.9    | 3.6    | 6.3    | 9      | 0      |        |        |         |         |         |
| Cust 8 | 10.3 | 14.6 | 8.5    | 6.2    | 13.8   | 7.4    | 6.1    | 14.3   | 0      |        |         |         |         |
| Cust 9 | 7.1 | 10.4   | 12.7   | 8.8    | 6.6    | 6.8    | 9.5    | 3.2    | 13.7   | 0      |         |         |         |
| Cust 10 | 11.8 | 15.5 | 17.8   | 13.3   | 12.8   | 9.8    | 10.5   | 9.7    | 15.8   | 6.5    | 0      |         |         |
| Cust 11 | 9.4 | 6.4    | 5.5    | 6.7    | 11.1   | 10.6   | 10.1   | 14.3   | 9.2    | 16.3   | 20.3   | 0      |         |
| Cust 12 | 8.8 | 8.2    | 5.8    | 7      | 11.8   | 10.9   | 10.3   | 14.6   | 6      | 15.3   | 20.5   | 3.9    | 0      |

### 3.2. Identification Saving Matrix

Second, based on distance matrix data, distance saving can be made by combining two trips into one trip. For saving the distance of consumer 1 and consumer 2 the calculation is as follows. Distance savings can be calculated using the formula:

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

\[
S(1, 2) = J(DC, 1) + J(DC, 2) - J(1, 2)
\]

\[
= 4.7 + 6.2 - 5.3 = 5.6
\]
Table 3. Saving Matrix

| Cust 1 | Cust 2 | Cust 3 | Cust 4 | Cust 5 | Cust 6 | Cust 7 | Cust 8 | Cust 9 | Cust 10 | Cust 11 | Cust 12 |
|--------|--------|--------|--------|--------|--------|--------|--------|--------|---------|---------|---------|
| 0      |        |        |        |        |        |        |        |        |         |         |         |
| Cust 2 | 5.6    | 0      |        |        |        |        |        |        |         |         |         |
| Cust 3 | 4.8    | 5.3    | 0      |        |        |        |        |        |         |         |         |
| Cust 4 | 3.4    | 1.3    | 0.4    | 0      |        |        |        |        |         |         |         |
| Cust 5 | 0.7    | 1.3    | 3.3    | 0.7    | 0      |        |        |        |         |         |         |
| Cust 6 | 3.5    | 4.1    | 6.4    | 1.1    | 6.6    | 0      |        |        |         |         |         |
| Cust 7 | 2.2    | 0.1    | 1.9    | 6.2    | 3.3    | 2.7    | 0      |        |         |         |         |
| Cust 8 | 0.4    | 8      | 8      | 0.4    | 6.6    | 10     | 1.9    | 0      |         |         |         |
| Cust 9 | 1.4    | 0.6    | 2.2    | 4.4    | 4      | 3.4    | 9.8    | 3.7    | 0       |         |         |
| Cust 10| 1      | 0.2    | 2.4    | 2.9    | 5.7    | 7.1    | 8      | 6.3    | 12.4    | 0       |         |
| Cust 11| 7.7    | 10.1   | 6.6    | 2.2    | 2.5    | 5.1    | 1      | 10.5   | 0.2     | 0.9     | 0       |
| Cust 12| 5.3    | 9.2    | 5.7    | 0.9    | 1.6    | 4.3    | 0.1    | 13.1   | 0.6     | 0.1     | 14.3    | 0       |

3.3. Consumer Allocation to Route

The last step, the division of the route is carried out with restrictions in the form of vehicle capacity, service time and vehicle capacity layout. For vehicle capacity of 2000 kg for 1 fuso truck and 800 kg for box car. Service time is starting from 10.30 - 14.00 WIB. One fuso truck can accommodate 5 vehicles and 1 box car can accommodate 2 vehicles. Route 1 is a route with fuso truck vehicles. Then for the second route is the delivery of a box car with a capacity of 800 kg.

Based on table IV and V, the first route is the distribution using Fuso trucks with a capacity of 2000 kg but from the results of saving the matrix only 450 kg transports. Second route is the distribution using Box Car with a capacity of 800 kg but from the results of saving the matrix only 181 kg transports. This is because the layout of the truck is confined because it transports the vehicle to be sent. In addition, it also considers the delivery time. It can be seen that shipments are made at 10:30 - 14:00 Western Indonesia Time (WIB).

While on route 1 using the Google Maps application it can be seen that the total distance traveled is 68.8 km, where the travel time is around 1 hour 55 minutes. This time does not exceed the available time, even though there is a break in the delivery time. Compared with the time availability of 3 hours 30 minutes minus, assuming there is no traffic congestion in the process of delivering goods, the rest time which is 2 hours 30 minutes, the time allocation on the first route is where it is used for loading / unloading time and service time. Whereas on the second route with total travel time is 38.1 km with a travel time of 1 hour 47 minutes and the remaining time for loading / unloading and service is 43 minutes.

In the calculation of costs, there are several elements of costs used to calculate delivery costs. The calculation of delivery costs is based on the route that has been obtained in the calculation with the saving matrix method. Then it will be compared to the current conditions or actual costs.

Table 4. Distribution Route 1

| Step 1     | Step 2     | Step 3     | Step 4     | Step 5     | Step 6     | Capacity |
|------------|------------|------------|------------|------------|------------|----------|
| Load 1     | 258        | 303        | 338        | 346        | 350        | 450      | 2000     |
Table 5. Distribution Route 2

| Step 1 | Step 2 | Step 3 | Step 4 | Capacity |
|--------|--------|--------|--------|----------|
| Route 2 DC-9-10-DC | DC-9-10-7-DC | DC-9-10-7-4-DC | DC-9-10-7-4-5-DC |
| Load 2 126 | 146 | 171 | 181 | 800 |

Table 6. Cost Elements

| Elements | Cost/day |
|----------|----------|
| Fuel     | IDR 7,800.00 |
|          | Truck 7km/l |
|          | Car 10km/l |
| Labor    | Driver IDR 60,000.00 |
|          | Porter IDR 43,333.33 |
|          | Out of Town (+) IDR 30,000 |
| Maintenance | Truck IDR 50,000.00 |
|          | Car IDR 30,000.00 |

Based on table VII, on route 1 with a total distance of 68.8 km, the total shipping cost is IDR 289,996.19 and route 2 with a total distance of 38.1 km, the total shipping cost is IDR 223,051.33.

Table 7. Distribution Route Cost

| Route | Distance (km) | Fuel Price | Labor | Maintenance | Total Cost |
|-------|---------------|------------|-------|-------------|------------|
| Route 1 DC-11-12-8-6-3-2-1-DC | 68.8 | IDR 51,368.57 | IDR 163,333.33 | IDR 50,000.00 | IDR 289,996.19 |
| Route 2 DC-9-10-7-4-5-DC | 38.1 | IDR 30,108.00 | IDR 163,333.33 | IDR 30,000.00 | IDR 223,051.33 |

From both routes it was found that there was a cost savings from the real condition cost of IDR 300,000.00. On the first route there was a savings of IDR 10,003.81 per day and a second route savings that was IDR 76,948.67 per day, resulting in savings in distribution costs of delivery goods.

Figure 2. Cost Comparison Chart
To measure the extent of the actual difference or actual error, validation of the method used is carried out. The validation of the results obtained in the saving matrix method is done by checking with Google Maps so the results are in the form of distances that can be compared with the results in the saving matrix method.

| Table 8. Validation |
|----------------------|
| Route | Distance (km) | Saving |
| Saving Matrix | Route 1 | 68.8 | 3.33% |
| | Route 2 | 38.1 | 25.65% |
| Google Maps | Route 1 | 46.1 | 12.00% |
| | Route 2 | 38.6 | 25.52% |

Based on table VIII, from the results of validation using google maps, the distance value on route 1 is 46.1 km where there is a difference with the value obtained from the calculation using the saving matrix method. On the second route there is a difference in value. The first route the value of Google Maps is smaller than the result of saving matrix. While the second route results from saving matrix are smaller than the results of Google Maps validation. Then from these results it can be concluded that the saving matrix value is directly proportional to the value obtained on Google Maps.

4. Conclusion
This study aims to solve delivery problems in courier service companies in Surakarta so that a minimum distribution cost is obtained by considering the vehicle capacity, service time and layout of goods in the vehicle. In determining the distribution route, this is only done on the distribution of goods in the Surakarta area and its surroundings, the number of requests per customer can be known from the company. The contribution of this article is not on the development of models in determining distribution routes, but on the use of the saving matrix method then the authors provide SOP so distribution managers at the company can easily apply the SOP combined with the use of excel spreadsheets for determine distribution routes. From the calculation results using the saving matrix method, there are 2 distribution routes. The first route is for fuso truck vehicles with a total distance of 68.8 km and travel time is 1 hour 55 minutes with a total cost of IDR 289,996.19 with a cost savings of 3%. The second route is for box car vehicles with a total distance of 38.1 km with a travel time of 1 hour 47 minutes with a total cost of IDR 223,051.33 with a cost savings of 25.65%. Therefore determining the distribution route greatly affects the distribution costs. In addition, the delivery time limit, the number of vehicles, the capacity of the vehicle also need to be considered so that the resulting route can be optimized so as to optimize distribution costs.

The development of this article can be done by considering the limitations in processing data such as traffic density, retrieval of goods from train stations where goods from outside the city will be sent in the city and others.

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