# DETERMINING THE BEST DISTRIBUTION ROUTE

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## Abstract

*The purpose of this research is to discuss demand forecasting, using several methods. The demand forecasting for the coming period also provides a basis for determining the best distribution route using the Matrix Saving method, with the consumer sequencing procedure. In the calculation of demand forecasting, in addition to the manual method, is a quantitative test method. The best method is obtained based on MAD and MSE, which is the linear regression method, because the forecasting error result is the smallest. In determining the route, the best procedure is the one that can produce the smallest distribution distance. In this research, the farthest insert procedure can produce the optimum distribution distance for each company vehicle.*

**Keywords:** Forecasting, Demand, Route, Saving Matrix

## บทคัดย่อ

วัตถุประสงค์ของงานวิจัยนี้ เพื่อศึกษาการพยากรณ์อุปสงค์โดยใช้วิธีการต่าง ๆ การพยากรณ์อุปสงค์สำหรับช่วงเวลาที่จะมาถึง ยังเป็นพื้นฐานในการกำหนดเส้นทางกระจายสินค้าที่ดีที่สุด โดยการใช้วิธี Matrix Saving โดยกระบวนการเรียงลำดับผู้บริโภค ทั้งนี้นอกเหนือจากการคำนวณด้วยมือ การพยากรณ์อุปสงค์ยังสามารถใช้วิธีการทดสอบเชิงปริมาณได้ ซึ่งวิธีที่ดีที่สุด คือ การใช้ linear regression เพื่อหาค่า MAD และ MSE ที่ให้ผลคลาดเคลื่อนน้อยที่สุด วิธีการที่ดีที่สุดในการคำนวณหาเส้นทาง คือวิธีที่ให้ผลระยะทางในการกระจายสินค้าที่น้อยที่สุด จากงานวิจัยนี้วิธีการบรรทุกที่มากสุดสามารถให้ระยะทางกระจายสินค้าที่น้อยที่สุดสำหรับรถของแต่ละบริษัท

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# INTRODUCTION

## Background

PT Citra Mandiri Company (a pseudonym to preserve confidentiality) is in the bottled drinking water distribution field, for the Aqua brand. At the moment this company is focusing more on the Aqua gallon product as compared with other packaged drinking water products. Nowadays, meeting customer demand is a very difficult thing to do. This is because of the constantly changing customer demand from time to time, resulting in a serious challenge for this company. Other than demand, a company in the distribution field must identify the most appropriate routes for distribution. By knowing the best distribution route, the company can minimize its cost of delivery.

In every situation, the size of the demand for products or services is not easily known before it happens. On the contrary, there are a lot of activities which need to be completed before the customer demand can be identified. No company can be without demand forecasting activity, and where this is done for the activity planning requirement it needs to be done before the customer demand is actually received.

Distribution is an activity to shift a product from the supplier to the consumer in a supply chain. Distribution is critical if profit is to be earned by the company, because distribution will directly affect supply chain cost and consumer needs. The correct distribution web can be utilized to achieve many purposes in the supply chain, especially low cost and high response towards customer demand.

One very important operational decision in distribution management is the determination of delivery schedules and routes from one initial location to several destination locations. This kind of decision is very important for those who need to send goods from one location (e.g. regional warehouse) to various agents all over a city. Delivery decisions as well as routes to be completed by each vehicle will significantly affect the delivery cost.

Companies are not easily able to conduct demand forecasting activity because of fluctuating customer demand. In forecasting customer demand companies can use the past year sales figures. After that, data processing is conducted to determine the distribution and the data parameters for generating the best solution.

## Problem Identification

- How to determine the right forecasting method, based on customer demand, by using Naïve, Moving Average, Weighted Moving Average, Exponential Smoothing, Exponential Smoothing with Trend and Linear Regression methods.
- How data processing can be done by using the Saving Matrix method, and

which is the right procedure for nearest neighbor, farthest insert and nearest insert.

**Research Purpose**

- To determine the right demand forecasting method out of four methods.
- To determine the best route or distribution lane by the Saving Matrix method.

## RESEARCH METHODOLOGY

**Research Design**

In this study, three types of research are used: descriptive, qualitative and quantitative. The analysis method used is by survey and observation. Data collection is conducted in a cross-sectional manner where the data collection is only conducted once. All this is presented in Tables 1 and 2 below.

**Table 1. Research Design**

| Research Purpose | Research Type | Method Used | Analysis Unit | Time Horizon |
|---|---|---|---|---|
| T-1 | Descriptive | Survey | Sales Unit | Cross-sectional |
| T-2 | Descriptive | Survey | delivery Unit | Cross-sectional |

**Table 2. Operationalization of Research Variable**

| Variable | Sub-variable | Concept | Indicator |
|---|---|---|---|
| Forecasting (T-1) | - | An introduction of what will happen in the future. Forecasting will not occur in an absolute way as predicted. | o Naive<br>o Moving Average<br>o Weighted Moving Average<br>o Exponential Smoothing<br>o Exponential Smoothing With Trend<br>o Linear Regression |
| Route Deter-mination (T-2) | - | The route or distribution lane which will be done every time delivery to the customer is conducted. | Saving Matrix with procedures (nearest neighbor, farthest insert, and nearest insert)* |

*(insert = inserting additional customers into the original calculations)

**Type and Source of Data**

To support the research and the analysis, relevant and accurate data is needed, and must be obtained from a clear and credible source, by interviews (as shown in Tables 3 and 4 below).

**Table 3. Type and Source of Research Data**

| Research Purpose | Data Type | Data Source |
|---|---|---|
| T-1 | Quantitative Data | Primary Data |
| T-2 | Quantitative Data | Primary Data |

**Source:** Company (2011)

**Table 4. Data Collection Technique**

| Research Purpose | Data Collection Technique |
|---|---|
| T-1 | Interview |
| T-2 | Interview |

**Source:** Company (2011)

**Analysis Method**

The analysis methods used are Forecasting Analysis Method and Saving Matrix, as in Table 5 below.

**Table 5. Analysis Method**

| Research Method | Analysis Technique |
|---|---|
| T-1 | Forecasting |
| T-2 | Saving Matrix |

**Source:** Company (2011)

## RESULTS AND DISCUSSION

**Demand Forecasting**

**Table 6. Aqua gallon Linear Regression Equation Calculation**

| Month | Demand (y) | x | x2 | x*y |
|---|---|---|---|---|
| **January** | **49649** | **1** | **1** | **49649** |
| February | 47472 | 2 | 4 | 94944 |
| March | 50864 | 3 | 9 | 152592 |
| April | 48982 | 4 | 16 | 195928 |
| Mey | 56097 | 5 | 25 | 280485 |
| June | 62119 | 6 | 36 | 372714 |
| July | 69429 | 7 | 49 | 486003 |
| August | 62167 | 8 | 64 | 497336 |
| September | 57060 | 9 | 81 | 513540 |
| October | 62915 | 10 | 100 | 629150 |
| November | 52950 | 11 | 121 | 582450 |
| December | 62705 | 12 | 144 | 752460 |

| Month | Demand (y) | x | x2 | x*y |
|---|---|---|---|---|
| **January** | **57636** | **13** | **169** | **749268** |
| February | 57021 | 14 | 196 | 798294 |
| March | 62666 | 15 | 225 | 939990 |
| April | 67314 | 16 | 256 | 1077024 |
| Mey | 70615 | 17 | 289 | 1200455 |
| June | 64781 | 18 | 324 | 1160058 |
| July | 78977 | 19 | 361 | 1500563 |
| August | 80101 | 20 | 400 | 1602020 |
| September | 72616 | 21 | 441 | 1524936 |
| October | 83984 | 22 | 484 | 1847648 |
| November | 79730 | 23 | 529 | 1833790 |
| December | 78137 | 24 | 576 | 1875288 |
| **January** | **85706** | **25** | **625** | **2142650** |
| February | 76761 | 26 | 676 | 1995786 |
| March | 87608 | 27 | 729 | 2365416 |
| April | 97664 | 28 | 784 | 2734592 |
| Mey | 100177 | 29 | 841 | 2905133 |
| June | 98772 | 30 | 900 | 2963160 |
| July | 90458 | 31 | 961 | 2804198 |
| August | 86856 | 32 | 1024 | 2779392 |
| September | 81402 | 33 | 1089 | 2686266 |
| **Total** | **2341391** | **561** | **12529** | **44099180** |

**Note:** Aqua Gallon, is a trademarked name of mineral water in Indonesia

$$\bar{x} = \frac{\Sigma x}{n} = \frac{561}{33} = 17$$

$$\bar{y} = \frac{\Sigma y}{n} = \frac{2341391}{33} = 70951.24$$

$$b = \frac{\Sigma xy - n\bar{x}\bar{y}}{\Sigma x^2 - n\bar{x}^2} = \frac{44099180 - (33)(17)(70951.24)}{12529 - (33)(17)^2} = 1435.672$$

$$\alpha = \bar{y} - 6x = 70951.24 - 1435.672\,(17) = 46544.83$$

$$\hat{y} = 46244.83 + 1435.672\,x$$

**Table 7. Linear Regression Method Calculation**

| Bulan | Permintaan ( $Y_t$ ) | Peramalan $\hat{y} = a + bx$ | $Error\ (e_t)$ $y_t - \hat{y}$ | RSFE | $\lvert Error \rvert$ $\lvert e_t \rvert$ | Kumulatif $\lvert Error \rvert$ | $Error^2$ $e_t^2$ | Kumulatif $Error^2$ | Kumulatif MAD | Sinyal Penelusuran |
|---|---|---|---|---|---|---|---|---|---|---|
| Januari | 49649 | 47980.50 | 1668.50 | 1668.50 | 1668.50 | 1668.50 | 2783885.58 | 2783885.58 | 1668.50 | 1.00 |
| Februari | 47472 | 49416.17 | -1944.17 | -275.68 | 1944.17 | 3612.67 | 3779812.54 | 6563698.12 | 1806.34 | -0.15 |
| Maret | 50864 | 50851.85 | 12.15 | -263.52 | 12.15 | 3624.83 | 147.72 | 6563845.84 | 1208.28 | -0.22 |
| April | 48982 | 52287.52 | -3305.52 | -3569.04 | 3305.52 | 6930.34 | 10926449.25 | 17490295.09 | 1732.59 | -2.06 |
| Mei | 56097 | 53723.19 | 2373.81 | -1195.23 | 2373.81 | 9304.15 | 5634973.92 | 23125269.00 | 1860.83 | -0.64 |
| Juni | 62119 | 55158.86 | 6960.14 | 5764.91 | 6960.14 | 16264.29 | 48443520.98 | 71568789.98 | 2710.72 | 2.13 |
| Juli | 69429 | 56594.53 | 12834.47 | 18599.37 | 12834.47 | 29098.76 | 164723517.51 | 236292307.49 | 4156.97 | 4.47 |
| Agustus | 62167 | 58030.21 | 4136.79 | 22736.17 | 4136.79 | 33235.55 | 17113064.60 | 253405372.09 | 4154.44 | 5.47 |
| September | 57060 | 59465.88 | -2405.88 | 20330.29 | 2405.88 | 35641.43 | 5788248.95 | 259193621.04 | 3960.16 | 5.13 |
| Oktober | 62915 | 60901.55 | 2013.45 | 22343.74 | 2013.45 | 37654.88 | 4053980.90 | 263247601.94 | 3765.49 | 5.93 |
| November | 52950 | 62337.22 | -9387.22 | 12956.52 | 9387.22 | 47042.10 | 88119936.88 | 351367538.82 | 4276.55 | 3.03 |
| Desember | 62705 | 63772.89 | -1067.89 | 11888.62 | 1067.89 | 48110.00 | 1140397.60 | 352507936.41 | 4009.17 | 2.97 |
| Januari | 57636 | 65208.57 | -7572.57 | 4316.06 | 7572.57 | 55682.56 | 57343755.82 | 409851692.24 | 4283.27 | 1.01 |
| Februari | 57021 | 66644.24 | -9623.24 | -5307.18 | 9623.24 | 65305.80 | 92606709.60 | 502458401.84 | 4664.70 | -1.14 |
| Maret | 62666 | 68079.91 | -5413.91 | -10721.09 | 5413.91 | 70719.71 | 29310421.49 | 531768823.33 | 4714.65 | -2.27 |
| April | 67314 | 69515.58 | -2201.58 | -12922.67 | 2201.58 | 72921.29 | 4846963.30 | 536615786.63 | 4557.58 | -2.84 |
| Mei | 70615 | 70951.25 | -336.25 | -13258.93 | 336.25 | 73257.55 | 113066.75 | 536728853.38 | 4309.27 | -3.08 |
| Juni | 64781 | 72386.93 | -7605.93 | -20864.85 | 7605.93 | 80863.47 | 57850110.32 | 594578963.70 | 4492.42 | -4.64 |
| Juli | 78977 | 73822.60 | 5154.40 | -15710.45 | 5154.40 | 86017.87 | 26567859.98 | 621146823.68 | 4527.26 | -3.47 |
| Agustus | 80101 | 75258.27 | 4842.73 | -10867.72 | 4842.73 | 90860.60 | 23452033.85 | 644598857.53 | 4543.03 | -2.39 |
| September | 72616 | 76693.94 | -4077.94 | -14945.66 | 4077.94 | 94938.55 | 16629610.96 | 661228468.49 | 4520.88 | -3.31 |
| Oktober | 83984 | 78129.61 | 5854.39 | -9091.28 | 5854.39 | 100792.93 | 34273835.44 | 695502303.92 | 4581.50 | -1.98 |
| November | 79730 | 79565.29 | 164.71 | -8926.56 | 164.71 | 100957.65 | 27130.70 | 695529434.63 | 4389.46 | -2.03 |
| Desember | 78137 | 81000.96 | -2863.96 | -11790.52 | 2863.96 | 103821.60 | 8202255.43 | 703731690.05 | 4325.90 | -2.73 |
| Januari | 85706 | 82436.63 | 3269.37 | -8521.15 | 3269.37 | 107090.97 | 10688780.20 | 714420470.25 | 4283.64 | -1.99 |
| Februari | 76761 | 83872.30 | -7111.30 | -15632.45 | 7111.30 | 114202.28 | 50570616.14 | 764991086.38 | 4392.40 | -3.56 |
| Maret | 87608 | 85307.97 | 2300.03 | -13332.43 | 2300.03 | 116502.30 | 5290119.60 | 770281205.98 | 4314.90 | -3.09 |
| April | 97664 | 86743.65 | 10920.35 | -2412.07 | 10920.35 | 127422.66 | 119254131.49 | 889535337.47 | 4550.81 | -0.53 |
| Mei | 100177 | 88179.32 | 11997.68 | 9585.61 | 11997.68 | 139420.34 | 143944373.37 | 1033479710.84 | 4807.60 | 1.99 |
| Juni | 98772 | 89614.99 | 9157.01 | 18742.62 | 9157.01 | 148577.35 | 83850832.14 | 1117330542.98 | 4952.58 | 3.78 |
| Juli | 90458 | 91050.66 | -592.66 | 18149.96 | 592.66 | 149170.01 | 351248.25 | 1117681791.23 | 4811.94 | 3.77 |
| Agustus | 86856 | 92486.33 | -5630.33 | 12519.62 | 5630.33 | 154800.34 | 31700660.95 | 1149382452.18 | 4837.51 | 2.59 |
| September | 81402 | 93922.01 | -12520.01 | -0.38 | 12520.01 | 167320.35 | 156750550.24 | 1306133002.42 | 5070.31 | 0.00 |

**Source:** author (2012)

$$\hat{Y}oktober = a + bx = 46544.83 + 1435.672(34) = 95,357.66$$

$$MAD = \frac{\text{E(permintaan aktual - peramalan)}}{n} = \frac{167320.4}{33}$$

$$= 5070.31$$

$$MSE = \frac{\text{E(kesalahan peramalan)}^2}{n} = \frac{1306133002}{33} = 39,579,787.94$$

$$Singal\ Penelusuran = \frac{RSFE}{MAD} = \frac{-0.38}{5,070.3} = 0.000075\ MAD$$

MAD = sum of (Actual demand-forecasting)/n

MSE = sum of (forecasting error)$^2$

Tracing Signal = RSFE/MAD

**Determination of Transportation Routes**

The calculation for determining the route to transmit consumers' request orders from the company uses the Saving Matrix method. Here are the metric factors that must be determined:

1. **Identify the Distance element of the Matrix**
   The first step is to find the location of the companies and its agents on a map (there are 30 such consumers in this study). To simplify determination of the routes, the purposes of transmission are viewed on a map with the help of the mapping program Google Earth. After that, the dots obtained are made into an X-axis scale and Y-axis, with P0 dot (the company's warehouse) as the center of coordinates (0,0).

**Table 8. Destinations of Transportation**

| Code | Name of Agency | (X) Coordinates | (Y) Coordinates |
|---|---|---|---|
| P1 | Uskah Jaya Branch | 3 | 4.4 |
| P2 | Karunia Ilahi Branch | 7 | -1.6 |
| P3 | Karesota Branch | 5.2 | 4.5 |
| P4 | Esa Water Branch | 0.3 | 1.7 |
| P5 | Hendri Agency | -2.7 | -1.5 |
| P6 | Berkah Agency | 11.4 | -15.7 |
| P7 | Banyu Laris Branch | 3.5 | 2.4 |
| P8 | Garuda Agency | 6.4 | 6.9 |
| P9 | Sinar Pelangi Branch | 8.8 | 4.4 |
| P10 | Garuda Jaya Branch | 4.5 | 5.6 |
| P11 | Timbul Agency | 3.4 | 8.4 |
| P12 | Yanto Agency | -2.9 | -1.8 |
| P13 | Joyo Supermarket | 11.1 | 7.3 |
| P14 | Parkit Agency | 5.6 | 0.8 |
| P15 | Kasuari Agency | 0.5 | -2.9 |
| P16 | Kardi Agency | 18.1 | -5.0 |
| P17 | Pansil Agency | 4.3 | 1.9 |
| P18 | Plastik Agency | 6.2 | 10.2 |
| P19 | PJMI Agency | 2.0 | 6.2 |
| P20 | Pelita Branch | 10.7 | 7.2 |
| P21 | Puri Flamboyan Branch | 6.6 | 0.6 |
| P22 | Aphin Agency | 10.7 | 10.8 |
| P23 | Rosalia Agency | 4.3 | -21.6 |
| P24 | Iis Agency | 5.4 | 9.4 |
| P25 | Nusa Jaya Branch | 10.7 | 7.9 |
| P26 | Null Agency | 0.8 | 2.8 |
| P27 | Oyok Agency | 8.9 | 9.8 |
| P28 | Berinomas Branch | 27.4 | 22.4 |
| P29 | Berinomas 2 Branch | 2.5 | 8.7 |
| P30 | Living Water Branch | 6.7 | 7.1 |

The coordinates of each agent thus obtained, are then used to calculate each matrix agent's distance, as in this example:

Gap P1 and P2[J(1,2)]:

$$J(1,2) = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

$$J(1,2) = \sqrt{(3-7)^2 + (4.4-(-1.6))^2}$$

$$J(1,2) = \sqrt{52}$$

$$J(1,2) = 7.21$$

The distance from the company to the destination of transmission, and the distance between the places of transmission on the map, can be obtained by drawing a straight line between the coordinates of each, point regardless of the actual road. Additional barrier points are expected to represent the state of the road, so that the distance obtained can be close to the actual distance. Below are the calculations:

**Table 9. Distinction of Distance**

| Name of Agency | Distance of travel time | Distance from map | The Distinction |
|---|---|---|---|
| Uskah Jaya Branch | 9.15 | 5.33 | 3.82 |
| Karunia Ilahi Branch | 10.85 | 7.18 | 3.67 |
| Karesota Branch | 11.65 | 6.88 | 4.77 |
| Esa Water Branch | 5 | 1.73 | 3.27 |
| Hendri Agency | 8.35 | 3.09 | 5.26 |
| Berkah Agency | 23.35 | 19.40 | 3.95 |
| Banyu Laris Branch | 10 | 4.24 | 5.76 |
| Garuda Agency | 15 | 9.41 | 5.59 |
| Sinar Pelangi Branch | 15.85 | 9.84 | 6.01 |
| Garuda Jaya Branch | 11.65 | 7.18 | 4.47 |
| Timbul Agency | 12.5 | 9.06 | 3.44 |
| Yanto Agency | 6.65 | 3.41 | 3.24 |
| Joyo Supermarket | 16.65 | 13.29 | 3.36 |
| Parkit Agency | 10 | 5.66 | 4.34 |
| Kasuari Agency | 5 | 2.94 | 2.06 |
| Kardi Agency | 23.35 | 18.78 | 4.57 |
| Pansil Agency | 6.65 | 4.70 | 1.95 |
| Plastik Agency | 17.5 | 11.94 | 5.56 |
| PJMI Agency | 11.65 | 6.51 | 5.14 |
| Pelita Branch | 16.65 | 12.90 | 3.75 |
| Puri Flamboyan Branch | 12.5 | 6.63 | 5.87 |
| Aphin Agency | 20 | 15.20 | 4.80 |
| Rosalia Agency | 25 | 22.02 | 2.98 |
| Iis Agency | 14.15 | 10.84 | 3.31 |
| Nusa Jaya Branch | 15.85 | 13.30 | 2.55 |
| Null Agency | 4.15 | 2.91 | 1.24 |
| Oyok Agency | 19.15 | 13.24 | 5.91 |
| Berinomas Branch | 39.15 | 35.39 | 3.76 |
| Berinomas 2 Branch | 15 | 9.05 | 5.95 |
| Living Water Branch | 13.35 | 9.76 | 3.59 |
| | | **Total** | **123.94** |

Average resistance value = 123.94 / 30 = 4.13 km.

2. **Identify a Saving Matrix**

A Saving matrix represents the savings when vehicles coincide in visiting some locations, compared with a vehicle that visits the locations one by one. An example of the calculation is:

Saving matrix S(1,2):

$S(1,2) = J(0, 1) + J(0,2) - D(1,2) = 9.46 + 11.31 - 11.34 =$ **9.43** km

3. **Allocate the Consumers to the Route**

After counting the values in the saving matrix, consumers will be grouped into a transmission route. In the allocation of consumers, important factors are the consumer's demand and the capacity of vehicle.

The first thing to do in determining the transmission route is sorting the saving matrix values, from the highest to the lowest. The pair of consumers with the highest saving matrix value will take the first rank from the routes and followed by the consumers with the second highest saving matrix value and so forth, until all the consumers are placed in a transmission route, taking into consideration that consumer requests will not exceed the capacity of a vehicle used in transmission. The result of the allocation can be seen in the Table below:

**Table 10. Consumer Allocation**

| Route | Vehicle | Consumer | Amount of the transmission (galon) |
|---|---|---|---|
| 1 | B 9249 QV | P6 - P23 - P22 - P28 - P25 | 340 |
| 2 | B 9543 AB | P13 - P27 - P20 - P16 | 305 |
| 3 | B 9248 HV | P18 - P24 - P30 - P9 | 315 |
| 4 | B 9542 PW | P8 - P11 - P29 - P2 | 340 |
| 5 | B 9734 JU | P10 - P3 - P19 - P21 | 335 |
| 6 | B 9654 FJ | P14 - P1 - P17 - P7 | 325 |
| 7 | B 9876 FLS | P5 - P12 - P15 - P26 - P4 | 325 |

**Note:** **B**xxxx**QV** is the cars area code in Indonesia
**B**xxxx code of car area number in Jakarta

4. **Sorting the consumers within a travel route**

After allocating the consumers into transmission routes, the next step is sorting the consumers in each travel route. Consumers will be sorted until we know which consumers should be visited first, so that the mileage and the vehicle operating costs can be minimized.

a) Consumer's route result with the greatest distance from the company (P0) is P28.

**Table 11. First Step Calculation of Farthest Insert Procedure**

| Route | Distance (km) |
|---|---|
| P0 - P6 - P0 | 47.06 |
| P0 - P23 - P0 | 52.30 |
| P0 - P22 - P0 | 38.66 |
| P0 - P28 - P0 | 79.04 |
| P0 - P25 - P0 | 34.86 |

b) The insertions of other consumers into the route from the previous step are as follows:

**Table 12. Second step calculation of Farthest Insert procedure**

| Route | Distance (Km) |
|---|---|
| P0 - P6 - P28 - P0 | 108.50 |
| P0 - P23 - P28 - P0 | 119.50 |
| P0 - P22 - P28 - P0 | 83.31 |
| P0 - P25 - P28 - P0 | 83.20 |

From the routes result above, the route with the greatest distance is that which inserts the consumer 23 (P23) into the route with a distance of 119.50 km.

c) After the insertion of the remaining consumers into the route which was obtained in the previous step and from each consumer, the route will be sought that generates the closest distance.

**Table 13. Third step calculation Farthest Insert procedure**

| Route | Distance (Km) |
|---|---|
| P0 - P6 - P28 - P23 - P0 | 148.96 |
| P0 - P28 - P6 - P23 - P0 | 124.48* |
| P0 - P28 - P23 - P6 - P0 | 130.24 |
| P0 - P22 - P28 - P23 - P0 | 123.77* |
| P0 - P28 - P22 - P23 - P0 | 127.29 |
| P0 - P28 - P23 - P22 - P0 | 149.84 |
| P0 - P25 - P28 - P23 - P0 | 123.66* |
| P0 - P28 - P25 - P23 - P0 | 126.24 |
| P0 - P28 - P23 - P25 - P0 | 145.10 |

From the lowest route obtained from each insertion per consumer (the lowest route marked with *), the route that generates the greatest distance was identified as P6 with route P0 - P28 - P6 - P23 - P0.

d) The insertion of the remaining consumers into the route obtained in the previous step and from each consumer, enables identification of the route that generates the closest distance.

**Table 14. Fourth step calculation Farthest Insert Procedure**

| Route | Distance (Km) |
|---|---|
| P0 - P22 - P28 - P6 - P23 - P0 | 128.75 * |
| P0 - P28 - P22 - P6 - P23 - P0 | 134.13 |
| P0 - P28 - P6 - P22 - P23 - P0 | 178.92 |
| P0 - P28 - P6 - P23 - P22 - P0 | 154.82 |
| P0 - P25 - P28 - P6 - P23 - P0 | 128.64 * |
| P0 - P28 - P25 - P6 - P23 - P0 | 133.02 |
| P0 - P28 - P6 - P25 - P23 - P0 | 173.18 |
| P0 - P28 - P6 - P23 - P25 - P0 | 150.08 |

From the shortest route that has been obtained from each insertion per consumer (the lowest route marked with *), a route is identified that generates the greatest distance, which is P22 with route P0 - P28 - P6 - P23 - P0.

e) The last step is inserting the last remaining consumer into the new route.

**Table 15. Last Step Calculation of Farthest Insertion procedure**

| Route | Distance (Km) |
|---|---|
| P0 - P25 - P22 - P28 - P6 - P23 - P0 | 133.88 |
| P0 - P22 - P25 - P28 - P6 -P23 - P0 | 137.57 |
| P0 - P22 - P28 - P25 - P6 - P23 - P0 | 137.29 |
| P0 - P22 - P28 - P6 - P25 - P23 - P0 | 177.45 |
| P0 - P22 - P28 - P6 - P23 - P25 - P0 | 154.35 |

From this last step, the route that has been obtained from the consumer 25 insertion (P25) is P0 - P25 - P22 - P28 - P6 - P23 - P0. By using the same steps, the order of the consumer and mileage for the next travel route can be seen in the Table below:

**Table 16. Sequencing visits with the Farthest**

| Load Route | Vehicle | Consumer | Distance (Km) |
|---|---|---|---|
| 1 | B 9249 QV | P0 - P25 - P22 - P28 - P6 - P23 - P0 | 133.88 |
| 2 | B 9543 AB | P0 - P16 - P13 - P20 - P27 - P0 | 70.39 |
| 3 | B 9248 HV | P0 - P24 - P18 - P30 - P9 - P0 | 49.02 |
| 4 | B 9542 PW | P0 - P29 - P11 - P8 - P2 - P0 | 49.70 |
| 5 | B 9734 JU | P0 - P19 - P10 - P3 - P21 - P0 | 41.80 |
| 6 | B 9654 FJ | P0 - P14 - P17 - P7 - P1 - P0 | 36.34 |
| 7 | B 9876 FLS | P0 - P15 - P12 - P5 - P26 - P4 - P0 | 40.13 |

**The Cost Calculation**

Data in the vehicle operating cost Table will be processed to obtain the transmission costs every day. The calculations are:

**a. Fuel Costs (Solar Gas)**

The fuel costs ratio that been used is **1:10**, which means that 1 liter of solar fuel can last for a distance of **10** km for one vehicle. From that ratio, the cost for a 1 km trip is IDR. 650. From that calculation, the cost can be obtained for each vehicle route.

**Table 17. The calculation of fuel costs each for each vehicle**

| No | Vehicle | Procedure | Distance (Km) | Costs |
|---|---|---|---|---|
| 1 | B 9249 QV | Farthest Insert | 133.88 | IDR. 87,022.00 |
| 2 | B 9543 AB | Farthest Insert | 70.39 | IDR. 45,753.50 |
| 3 | B 9248 HV | Farthest Insert | 49.02 | IDR. 31,863.00 |
| 4 | B 9542 PW | Farthest Insert | 49.70 | IDR. 32,305.00 |
| 5 | B 9734 JU | Farthest Insert | 41.80 | IDR. 27,170.00 |
| 6 | B 9654 FJ | Farthest Insert | 36.34 | IDR. 23,621.00 |
| 7 | B 9876 FLS | Farthest Insert | 40.13 | IDR. 26,084.50 |

**Note:** IDR is the name of Indonesia currency (Indonesian Rupee)

The depreciation cost of each vehicle is **10%** per year, and the total days per year determined by the company amount to **264** days. Thus, the company can determine the incurred cost per day, as follows:

- Depreciation costs truck B 9249 QV = IDR. 150.000.000,- x 10% : 264
  = IDR. 56.818,18 / day
- Depreciation costs truck B 9543 AB = IDR. 162.500.000,- x 10% : 264
  = IDR. 61.363,64 / day
- Depreciation costs truck B 9248 HV = IDR. 150.000.000,- x 10% : 264
  = IDR. 56.818,18 / day
- Depreciation costs truck B 9542 PW = IDR. 175.000.000,- x 10% : 264

= IDR. 66.287,88 / day

- Depreciation costs truck B 9734 JU = IDR. 160.000.000,- x 10% : 264
  = IDR. 60.606,06 / day
- Depreciation costs truck B 9654 FJ = IDR. 155.000.000,- x 10% : 264
  = IDR. 58.712,12 / day
- Depreciation costs truck B 9876 FLS = IDR. 160.000.000,- x 10% : 264
  = IDR. 60.606,06 / day

**Labor Costs**

At each occurrence of transmission activity, the company uses two workers (1 driver and 1 conductor). The incurred cost for driver and conductor is IDR. 112.500 per day.

**Vehicle Tax Costs**

Vehicle tax costs applicable to each operational vehicle cost can be calculated into cost per day, using this method:

- Tax costs truck B 9249 QV = IDR. 1.937.500,- : 264 = IDR. 7.339,02 / day
- Tax costs truck B 9543 AB = IDR. 2.032.500,- : 264 = IDR. 7.698,86 / day
- Tax costs truck B 9248 HV = IDR. 1.975.000,- : 264 = IDR. 7.481,06 / day
- Tax costs truck B 9542 PW = IDR. 2.325.000,- : 264 = IDR. 8.806,82 / day
- Tax costs truck B 9734 JU = IDR. 2.132.500,- : 264 = IDR. 8.077,65 / day
- Tax costs truck B 9654 FJ = IDR. 2.155.500,- : 264 = IDR. 8.164,77 / day
- Tax costs truck B 9876 FLS = IDR. 2.167.500,- : 264 = IDR. 8.210,23 / day

**Maintenance Costs**

Maintenance cost required every month is IDR 200.000 for each vehicle. The maintenance cost per day per truck = IDR. 200.000 / 22 = IDR. 9.090,91.

From the calculation of the costs above, we can obtain the company's expense for each shipment. Below are the measures of the company's expense based on the route and the vehicle, using several procedures to identify the shortest route.

a. Total costs for truck B 9249 QV *using Farthest Insert*
   Total Costs = IDR. 87,022.00 + IDR. 56.818,18 + IDR. 112.500,00 + IDR. 7.339,02 + IDR. 9.090,91
   = IDR. 272.770,11
b. Total costs for truck B 9543 AB *using Farthest Insert*
   Total Costs = IDR. 45,753.50 + IDR. 61.363,64 + IDR. 112.500,00 + IDR. 7.698,86 + IDR. 9.09,91
   = IDR. 236.595,41
c. Total costs for truck B 9248 HV *using Farthest Insert*

Total Costs = IDR. 31,863.00 + IDR. 56.818,18 + IDR. 112.500,00 + IDR. 7.481,06 + IDR. 9.090,91
= IDR. 217.753,15

d. Total costs for truck B 9542 PW *using Farthest Insert*
Total Costs = IDR. 32,305.00 + IDR. 66.287,88 + IDR. 112.500,00 + IDR. 8.806,82 + IDR. 9.090,91
= IDR. 228.990,61

e. Total costs for truck B 9734 JU *using Farthest Insert*
Total Costs = IDR. 27,170.00 + IDR. 60.606,06 + IDR. 112.500,00 + IDR. 8.077,65 + IDR. 9.090,91
= IDR. 217.444,62

f. Total costs for truck B 9654 FJ *using Farthest Insert*
Total Costs = IDR. 23,621.00 + IDR. 58.712,12 + IDR. 112.500,00 + IDR. 8.164,77 + IDR. 9.090,91
= IDR. 212.088,80

g. Total costs for truck B 9876 FLS *using Farthest Insert*
Total Costs = IDR. 26,084.50 + IDR. 60.606,06 + IDR. 112.500,00 + IDR. 8.210,23 + IDR. 9.090,91
= IDR. 216.491,70

## CONCLUSIONS

The conclusions from the analysis results are as follows:

1. From the results of calculations performed for the forecasting months of January 2009 to September 2011 for Aqua products gallon, using *Naive, Moving Average, Weighted Moving Average, Exponential Smoothing, Exponential Smoothing With Trend*, and a Linear Regression method, the lowest accuracy results are MAD and MSE forecasting Linear Regression methods.
2. After making the demand forecast for this product, then the data processing should be performed to determine the best distribution channel by using the *Saving Matrix* method. In this research, from the *farthest insertion* procedure can be obtained the smallest distribution route for each vehicle.

In order for the actual distribution operation to run smoothly, the following suggestions are offered to the company:

1. When planning to order products inventory for the warehouse, it is better first for the company to forecast demand based on demand data from the previous year. The company should make an inventory plan which anticipates demand in the next period, so as to minimize product inventory overstock and understock happening in the warehouse.

2. Before sending the product to the consumer, it is better to specify the distribution route in order to know which one is the best track to minimize delivery costs.

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