Distribution Cost Optimization Using Average Opportunity Cost Method and Average Total Opportunity Cost Method

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Abstract
Every company carries out distribution activities to distribute goods to consumers. PT Petrokimia Gresik is one of the providers of organic fertilizer called petragonik fertilizer. They must ensure that distribution from source to destinations does not occur scarcity of organic fertilizers. Selection of inappropriate distribution channels, very high transportation costs and to meet the number of different requests for each destination are factors that can hinder the process of distributing goods. The main aim of this research is to help PT Petrokimia Gresik in solving cost optimization problems related to the distribution of goods. The methods used in this research are Average Opportunity Cost Method (AOCM) and Average Total Opportunity Cost Method (ATOCM), then continued using Modified Distribution (MODI) for optimization test. Based on the research results, it is found that the initial cost of distribution using AOCM is smaller than ATOCM. So for the case of PT Petrokimia Gresik, the AOCM method is better than ATOCM. While the optimization test results get the minimum distribution cost of IDR194.350.000.

Keywords: Average Opportunity Cost Method, Average Total Opportunity Cost Method, Transportation Model

1. INTRODUCTION

The distribution system in Indonesia is growing very rapidly. A factor that greatly influences the success in selling goods or products of a company is the distribution problem. Distribution is important for a company that sells goods or products to consumers [1]. Distribution is part of marketing activities, where the delivery of goods from the source or company to the destination or the hands of consumers occurs [2]. The distribution process includes transportation costs, the amount of inventory and the amount of demand [3]. Choosing the right distribution channel will be able to minimize the distribution costs that must be borne by a company [4]. The company must be able to manage the costs to be incurred so that income is greater than expenses [5]. A distribution strategy is needed to calculate the minimal and costly transportation costs [6]. Therefore, the company needs a method to help solve the distribution problem so as to obtain the minimum possible distribution cost.

The distribution is done by applying a transportation model to obtain the minimum cost. The application of transportation models is expected to help solve cost problems in the distribution of goods [6]. Transportation models can organize the distribution of goods from a source to each destination by generating minimum costs [7]. The solution of the transportation model has two solutions, namely the initial feasible solution and the optimum solution. The initial feasible solution is to find an allocation of goods from each source to each destination. The optimum solution is to prove that the distribution process is optimal with minimal cost [9]. The solution methods for the initial feasible solution in this study are the Average Opportunity Cost Method (AOCM) and the Average Total Opportunity Cost Method (ATOCM). Meanwhile, the optimum distribution solution will be determined using the Modified Distribution (MODI) method.

The AOCM method for transportation problems has been discussed by Kamble and Bhausheb [10] in their research. This study compared the AOCM method with the NWCM, LCM, and VAM methods and found that the AOCM method is close to the optimal solution and better than the comparison method.
While ATOCM has been studied by Azad et al. [11], where their research compares the ATOCM method with the LCM method, VAM, and several other methods. They conclude that the ATOCM method is better than other comparison methods. Furthermore, other research on the ATOCM has been studied by Islam et al. [12] and found that ATOCM is better than other methods, except that in this study no optimization test was carried out.

Based on Kamble and Bhausaheb [10], Azad et al. [11] and Islam et al. [12] we review two methods, AOCM and ATOCM for different cases. This research is expected to get optimization results in solving the distribution cost problem.

2. RESEARCH METHODS

The data in this study were taken from the research of Muhammad Dwi Naffiqi Nugraha, et al, which has 5 sources and 7 destinations [13]. This section describes the steps that will be taken to get the minimum distribution cost.

2.1 Transportation Model

The distribution problem will be solved using the transportation model approach. The transportation model can help determine the distribution path so that the minimum cost is obtained [14]. According to Basriati et al. [15] transportation model is one form of model that can be used to solve problems related to the optimal distribution of goods of the same type, from a number of sources to a number of destinations. Allocation of goods must be managed properly to meet the availability of demand and inventory, as well as the transportation costs of each source and destination [16].

According to Taha [17], an overview of the transportation model can be seen from the Figure 1.

![Figure 1. Bipartite graph of transportation model](image)

Based on Figure 1, the transportation problem scheme consists of m sources and n destinations.

According to Siswanto [18], the transportation model is as follows:

Objective Function:
\[
\text{minimize } Z = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij} X_{ij}
\]

subject to
\[
\begin{align*}
\sum_{j=1}^{n} X_{ij} & = a_i \\
\sum_{i=1}^{m} X_{ij} & = b_j \\
X_{ij} & \geq 0 \text{ for all } i \text{ and } j
\end{align*}
\]

where
\[
\begin{align*}
Z & \quad : \quad \text{Total transportation cost}, \\
a_i & \quad : \quad \text{Supply in source } i, i = 1, 2, 3, ..., m, \\
b_j & \quad : \quad \text{Demand from destination } j, j = 1, 2, 3, ..., n, \\
c_{ij} & \quad : \quad \text{Transportation cost per unit from sources } i \text{ to destination } j, \\
X_{ij} & \quad : \quad \text{Quantity of goods distributed from source } i \text{ to destination } j.
\end{align*}
\]
2.2 Average Opportunity Cost Method

Besad on Kamble and Bhausaheb [10], the average oppurtunity cost method (AOCM) is a transportation method to find the initial feasible solution by finding the largest average penalty value for each row and column. The following are the steps for solving using the AOCM method:

a. Reduced the rows in the transportation table by substracting each cost element with the smallest cost and placing it to the upper right of the element.

b. Reduced the column in the transportation table in the same way and place it on the bottom right of the element.

c. Create an AOCM (Average Opportunity Cost Matrix) table where the elements are the average values of the top right and bottom right elements in Step a and b.

d. Calculate the penalty for each row and column. The penalty value is obtained by subtracting the second smallest value from the smallest value.

e. Selects the penalty for with the largest value in each row and column. If the values are the same, the highest value in the amount of inventory or demand is selected.

f. Next, the inventory or demand will be allocated to the element that has the least cost in the corresponding row or column. Then, the selected row or column will be shaded.

g. If each row or each column is fulfilled. Step h will continue. If not, repeat Steps d to f until the supply and demand are met.

h. Furthermore, the allocated values will be inserted into the original transportation table in the corresponding cells.

i. Then, the transportation costs generated from the table will be calculated.

2.3 Average Total Opportunity Cost Method

The steps for solving ATOCM are taken from research [11] as follows:

a. Reducing the rows in the transportation table, obtained from each element in the row is deducted by the cost with the smallest value in the row and placed on the top right of the element.

b. Reducing the transportation table column, obtained from each element in the column minus the cost with the smallest value in the column and placed at the bottom right of the element.

c. Create a the TOCT (Total Opportunity Cost Table), whose elements are the sum of the top and bottom right elements in Step a and Step b.

d. Find Row Average Total Opportunity Cost (RATOC) and Column Average Total Opportunity Cost (CATOC).

e. Next, the element with the highest value between RATOC and CATOC will be selected. If there are two or more RATOC and CATOC values that have the same value, the element with the highest value in the supply or demand value will be selected.

f. Will be allocated \( x_{ij} = \min(a_i, b_j) \) on the top left with the smallest entry \((i,j)\) to the transportation table.

g. If each row or column is satisfied, proceed to Step h. If not, Step d to f will be repeated until all supplies and demands have been met.

h. Next, the allocated values are inserted into the original transportation table in the cell which is in sync.

i. Then the transportation cost generated from the table will be calculated.

2.4 Modified Distribution Method (MODI)

The Modified Distribution (MODI) method will be used after the initial feasible solution has been obtained. According to Dimyati and Dimyati [14] MODI method is the development of the stepping stone method. The difference between MODI and the stepping stone method is that each non-base variable does not have to find all of its closed paths (loop), except when moving to fill the table. According to Soplanit et al. [19] MODI method can be used if it meets the \( m + n - 1 \) condition where \( m \) is the number of rows and \( n \) is te number of columns. There is following equation that will be used in the MODI method,

\[
U_i + V_j = C_{ij}
\]  

(2)

where \( U_i \) is the value in each row cell, \( V_j \) the value of each column cell, and \( C_{ij} \) transportation cost for goods per unit.
According to Nufus and Nurdin [20], the steps for solving MODI are as follows:

a. All base variables will be searched for the value of $U_i$ for each row cell and the value $V_j$ for each column cell using equation (2) and determine the value of $U_i = 0$.

b. For non-base variables, the change in cost will be determined $X_{ij}$ for each non-base variable using the following equation:

$$X_{ij} = C_{ij} - U_i - V_j.$$  

(3)

c. If the calculation obtained $X_{ij}$ is already positive, meaning that the initial solution obtained previously is optimal. If the value $X_{ij}$ obtained is still negative, we will continue by selecting $X_{ij}$ the largest negative value to be used as entering variable.

d. Will be allocated the value to be used as entering variable $X_{ij}$ the same as the step on the stepping stone and repeat the first step until the value of $X_{ij}$ are no longer negative.

### 3. RESULTS AND DISCUSSION

PT. Petrokimia Gresik is one of the providers of organic fertilizer products called petroganic fertilizer. PT. Petrokimia Gresik is located at Jl. Jendral A. Yani Gresik, East Java. PT. Petrokimia Gresik has five distribution points, namely Wotan Panceng, Gresik industrial Estate, Panceng, Kebomas, and Wadeng. The destination areas that request fertilizer supplies are GMG Warehouse, Bojonegoro Warehouse, Pucuk Warehouse, Jenuh Warehouse, Palang Warehouse, Pusri Warehouse, and Weru Warehouse. The data in November 2020 distributed to warehouses that request the fertilizer stock amounting to IDR217,100,000 are given in Table 1.

<table>
<thead>
<tr>
<th>Sbr</th>
<th>Freight Cost (in thousands IDR)</th>
<th>Psd (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Sbr</th>
<th>Freight Cost (in thousands IDR)</th>
<th>Psd (tons)</th>
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<tbody>
<tr>
<td></td>
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<td>2</td>
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<tr>
<td>1</td>
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<td>2</td>
<td>X_{11}</td>
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<td>X_{11}</td>
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<tr>
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<td>X_{11}</td>
<td>X_{11}</td>
</tr>
<tr>
<td>5</td>
<td>X_{11}</td>
<td>X_{11}</td>
</tr>
</tbody>
</table>

Description:

- **Sbr**: Source
- **Psd**: Supplies
- **Pmt**: Inquiry

Source 1 : Wotan Panceng
Source 2 : Gresik Industrial Estate
Source 3 : Panceng
Source 4 : Kebomas
Source 5 : Wadeng
Objective 1 : GMG Warehouse
Destination 2 : Bojonegoro Warehouse
Destination 3 : Pucuk Warehouse
Objective 4 : Jenuh Warehouse
Objective 5 : Palang Warehouse
Objective 6  : Pusri Warehouse  
Destination 7  : Weru Warehouse

Based on Table 1, the following transportation model can be formed:

\[
\text{minimize } Z = 40X_{11} + 40X_{12} + 55X_{13} + 50X_{14} + 50X_{15} + 45X_{16} + 45X_{17} + 45X_{21} + 45X_{22} + 40X_{23} + 55X_{24} + 55X_{25} + 50X_{26} + 50X_{27} + 40X_{31} + 50X_{32} + 40X_{33} + 40X_{34} + 45X_{35} + 40X_{36} + 35X_{37} + 40X_{41} + 55X_{42} + 50X_{43} + 55X_{44} + 45X_{45} + 50X_{46} + 50X_{47} + 35X_{51} + 45X_{52} + 40X_{53} + 45X_{54} + 50X_{55} + 40X_{56} + 40X_{57}.
\]

subject to

\[
\text{Supply: } X_{11} + X_{12} + X_{13} + X_{14} + X_{15} + X_{16} + X_{17} = 1300; \\
X_{21} + X_{22} + X_{23} + X_{24} + X_{25} + X_{26} + X_{27} = 1030; \\
X_{31} + X_{32} + X_{33} + X_{34} + X_{35} + X_{36} + X_{37} = 910; \\
X_{41} + X_{42} + X_{43} + X_{44} + X_{45} + X_{46} + X_{47} = 780; \\
X_{51} + X_{52} + X_{53} + X_{54} + X_{55} + X_{56} + X_{57} = 780.
\]

\[
\text{Demand: } X_{11} + X_{21} + X_{31} + X_{41} + X_{51} = 1110; \\
X_{12} + X_{22} + X_{32} + X_{42} + X_{52} = 1020; \\
X_{13} + X_{23} + X_{33} + X_{43} + X_{53} = 630; \\
X_{14} + X_{24} + X_{34} + X_{44} + X_{54} = 630; \\
X_{15} + X_{25} + X_{35} + X_{45} + X_{55} = 540; \\
X_{16} + X_{26} + X_{36} + X_{46} + X_{56} = 450; \\
X_{17} + X_{27} + X_{37} + X_{47} + X_{57} = 420.
\]

\[
X_{ij} \geq 0 \text{ for all } i \text{ and } j \quad (4)
\]

where \(X_{ij}\) is the amount of petroorganic fertilizer that must be distributed from the source \(i\) to destination \(j\), for \(i = 1, 2, 3, 4, 5\) and \(j = 1, 2, 3, 4, 5, 6, 7\).

a. Settlement using the Average Opportunity Cost Method (AOCM)

The initial transportation table AOCM can be constructed from Table 1 as seen in Table 2.

<table>
<thead>
<tr>
<th>Sbr</th>
<th>1</th>
<th>2</th>
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<th>6</th>
<th>7</th>
<th>Prs (tons)</th>
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<tbody>
<tr>
<td>1</td>
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<td>55</td>
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<td>1300</td>
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<td>Pmt (tons)</td>
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<td>1020</td>
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<td>540</td>
<td>450</td>
<td>420</td>
<td>4800</td>
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</tbody>
</table>

The final results using AOCM after 11 iterations can be seen in Table 3.
**Table 3. Final Results using AOCM**

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<td>540</td>
<td>450</td>
<td>420</td>
<td>4800</td>
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</tbody>
</table>

Based on Table 3, the values obtained $Z$ i.e:

$Z = (40 \times 280) + (40 \times 1020) + (40 \times 630) + (55 \times 400) + (40 \times 630) + (35 \times 280) + (40 \times 780) + (35 \times 50) + (50 \times 140) + (40 \times 450) + (40 \times 140)$

$= 197750 \times 1000$

$Z = 197.750.000$

So, the initial solution to the cost of distributing petroganic fertilizer at PT. Petrokimia Gresik using AOCM is obtained in the amount of IDR 197,750,000.

b. Settlement using the Average Total Opportunity Cost Method (ATOCM)

The initial transportation table for ATOCM can also be constructed from Table 1 to obtain Table 4.

**Table 4. Initial Transportation Data using ATOCM**

<table>
<thead>
<tr>
<th>Sbr</th>
<th>1</th>
<th>2</th>
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<th>6</th>
<th>7</th>
<th>Psd (tons)</th>
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<td>Pmt</td>
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<td>1020</td>
<td>630</td>
<td>630</td>
<td>540</td>
<td>450</td>
<td>420</td>
<td>4800</td>
</tr>
</tbody>
</table>

The final results using ATOCM after 11 iterations can be seen in Table 5.
Dist Cost Optimization Using Average Opportunity Cost Method & Average Total Opportunity Cost Method

Table 5. Final Results using ATOCM

<table>
<thead>
<tr>
<th>Sbr</th>
<th>Freight Cost (in thousands)</th>
<th>Psd (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>330 620 260 90</td>
<td>1300</td>
</tr>
<tr>
<td>2</td>
<td>45 400 630</td>
<td>1030</td>
</tr>
<tr>
<td>3</td>
<td>40 50 630 280</td>
<td>910</td>
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<tr>
<td>4</td>
<td>780</td>
<td>780</td>
</tr>
<tr>
<td>5</td>
<td>360 420 780</td>
<td></td>
</tr>
<tr>
<td>Pmt</td>
<td>1110 1020 630 630 540 450 420</td>
<td>4800</td>
</tr>
</tbody>
</table>

Based on Table 5, The value $Z$ i.e:

\[
Z = (40 \times 330) + (40 \times 620) + (50 \times 260) + (45 \times 90) + (45 \times 400) + (40 \times 630) + (40 \times 630) + (45 \times 280) + (40 \times 780) + (40 \times 420)
\]

\[
= 198450 \times 1000
\]

\[
Z = 198.450.000.
\]

So, the initial solution to the cost of distributing petroganic fertilizer at PT. Petrokimia Gresik using ATOCM is IDR 198.450.000.

c. Optimization Test using Modified Distribution (MODI)

Testing using MODI can be done if it meets (m+n-1) where m is the number of rows and n is the number of columns. In this study, these conditions have been met so that the optimization test can be continued.

1) Optimizing petroganic fertilizer transportation costs with an initial feasible solution using the Average Opportunity Cost Method (AOCM)

Based on Table 3, we will calculate the index value in each filled row column for the first iteration using Equation 2. Next, calculate the cost change for each empty cell in the first iteration using Equation 3. X_{ij} for each empty cell of the first iteration using Equation 3. untuk setiap sel kosong iterasi pertama dengan menggunakan Persamaan 3.

Iteration I is not optimal, because there are negative results. X_{ij} which is negative. Then continue to find the index value for iteration II, until there are no more negative results. X_{ij} which is negative. After iterating 2 times, he optimal results using AOCM with the optimal test MODI are obtained in Table 6.
Based on Table 6, the value results are Z as follows:
\[ Z_2 = (40 \times 280) + (40 \times 1020) + (45 \times 400) + (40 \times 630) + (40 \times 630) + (35 \times 280) \\
+ (40 \times 240) + (45 \times 540) + (35 \times 190) + (40 \times 450) + (40 \times 140) \\
= 194350 \times 1000 \\
Z_2 = 194350.000. \\
So that the cost solution for the distribution of petroganic fertilizer of PT. Petrokimia Gresik obtained from MODI is IDR.194.350.000 and is the optimal solution.

2) Optimizing petroganic fertilizer transportation costs with an initial feasible solution using the Average Total Opportunity Cost Method (ATOCM)

Based on Table 5, calculate the index value in each filled row and column for the first iteration using Equation 2. Next, calculate the change in cost \( X_{ij} \) for each empty cell of the first iteration using Equation 3. Iteration I is not optimal. Because there are negative results. \( X_{ij} \) which is negative. Then continue to find the index value for iteration II, until there are no more negative results. \( X_{ij} \) which is negative. After iterating 3 times, the optimal results using ATOCM with the optimal test using MODI are obtained in pada Table 7.

Based Table 7, the value results are Z as follows:
\[ Z_3 = (40 \times 680) + (40 \times 620) + (45 \times 400) + (40 \times 630) + (40 \times 630) + (35 \times 280) \\
+ (40 \times 240) + (45 \times 540) + (35 \times 190) + (40 \times 450) + (40 \times 140) \\
= 194350 \times 1000 \\
Z_3 = 194350.000. \\
So that the cost solution for the distribution of petroganic fertilizer of PT. Petrokimia Gresik obtained from MODI is IDR.194.350.000 and is the optimal solution.
5. CONCLUSION

The solution of the petroganic fertilizer distribution problem PT. Petrokimia Gresik, results in that initial feasible solution for the minimum cost of fertilizer distribution using the Average Opportunity Cost Method (AOCM) get a smaller cost than the distribution cost using the Average Total Opportunity Cost Method (ATOCM). So it can be concluded that AOCM is better than ATOCM for case of PT. Petrokimia Gresik above. The optimal fertilizer distribution cost obtained using modified distribution (MODI) is IDR194,350,000.

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