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# SOLVING LARGE SCALE TRANSPORTATION PROBLEM IN FERTILIZER DISTRIBUTION TO MINIMIZE TRANSPORTATION COST

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***Abstract*** *Indonesia is agricultural country which have high degree of dependency to the fertilizer availability, it is because fertilizer has important role for the land fertility. Fertilizer is needed by the farmers all the time, from the initial period of planting the crop to the harvest period. This condition requires the fertilizer industry to be able to deliver fertilizer exactly when fertilizer is needed. The complexity of the transportation problem is indicated by the number of nodes in the model that represent both source and destination. In the distribution of fertilizer, the number of sources is relatively small, but the number of destinations is very large, where the number reaches 50 destination points. In solving large scale transportation complex problems, modeling techniques using Linier Programming are needed. Fertilizer demands are fulfilled from 42 buffer warehouses, and the optimal allocation for petrochemical distribution is supplied by 47 production partners. Based on the results of the calculation process using linier programming, the optimal distribution cost is 939,854,960.00 rupiahs. Meanwhile, the initial cost of distribution is IDR 1,032,267,660.00. There was a decrease of 92,412,700.00 rupiahs or about 9%. Optimization of the distribution process is also marked by the decrease in the number of production partners needed to meet the needs of 42 buffer warehouses. In the initial distribution, 56 production partners sent their products, after the calculation process only 47 production partners were needed.*

***Keywords****: distribution, linier programming, fertilizer, transportation.*

## 1. Introduction

Indonesia is an agrarian country where most of the population are farmers. The concept of an agrarian Indonesian state is a doctrine developed by the Dutch East Indies colonial government, especially since the entry of the plantation economic system in the archipelago. This condition resulted in a high demand for products supporting the agricultural sector. One commodity that is a key component in the agricultural sector is fertilizer. Fertilizers are needed at all times for farmers, both during the early planting period and during the plant maintenance period. This condition requires the fertilizer industry to be able to send fertilizer just in time when fertilizer is needed. The complexity of the transportation problem is shown by the number of nodes in the model that represent the source and destination. In the distribution of fertilizers, the number of sources is relatively small but the number of destinations is very large where the number reaches 50 destination points.

The transportation problem is one of the optimization problems where the objective function is to minimize distribution costs for certain products from a source to a number of destinations. In complex problems, of course, it will be difficult to do the simplex method manually. Thus, it is needed a modeling technique with a certain algorithm to solve this problem.

There are several studies that try to solve transportation problems. Joshi (2013) uses MODI to solve transportation problems. Ahmad (2012) solves transportation problems using The Best Candidate Method. Genetic Algorithm is used by Kumar (2004) as an algorithm to solve transportation problems by reducing costs and time to get a relatively faster solution than using the Linear Programming method. Based on the research that has been done, it is necessary to solve problems in fertilizer distribution that is categorized as a largescale transportation

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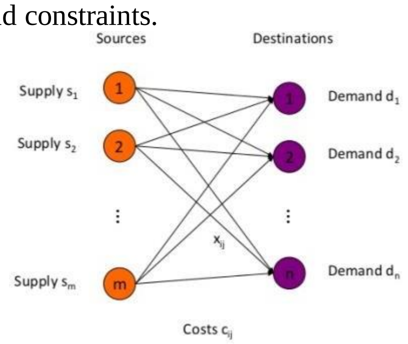
problem using linear programming. The results of this study are expected to provide recommendations for fertilizer distribution routes with minimal transportation costs.

## 2. Methods

### 2.1 Transportation Problem Concept

The transportation problem is a special type of problem that is part of the linear programming problem. This problem relates to the delivery of commodities from sources such as factories to destinations such as warehouses. The purpose of the transportation problem is to determine the delivery schedule to minimize the total transportation costs but meet the supply and demand constraints.




Graphic 1. Transportation Problem Illustration

### 2.2 Linear Programming

Linear Programming is a method for solving optimization problems. In 1947, George Dantzig developed the simplex algorithm method to solve linear programming problems. Since then, linear programming has been used to solve optimization problems in several industrial sectors, including banking, education, forestry, petroleum, and manufacturing (Winston, 1991). The steps in making the formulation of a mathematical model are as follows:

1. Define the problem.
2. Formulate a mathematical model.
3. Measuring validity.
4. Implementation of decisions.

### 2.3 General Formulation of Linear Programming Model

The decision-making problem that is often faced in decision-making is the optimum allocation of scarce resources. Resources can be money, labor, raw materials, machine capacity, time, space, or technology. Formulate decision formulations to get the best results while taking into account the limitations of existing resources. The best results to be achieved are represented in the form of maximizing everything that is equated with profits such as sales, welfare and productivity or minimizing everything that is equated with costs such as time, distance and labor. One method that is considered to be able to solve decision-making problems with linear functions is linear programming. Based on the illustration above, linear programming is considered capable of being used to assist decision makers in planning and making decisions about the allocation of resources to obtain optimum results.

There are several stages after the problem is identified and the objectives are set, the next step is the formulation of a mathematical model which includes the following three stages:

1. Determine the unknown variable (decision variable) and express it in mathematical symbols.
2. Forming the objective function which is shown as a linear relationship (not multiplication) of the decision variables.
3. Determine all the constraints of the problem and express in equations or inequalities which are also linear relationships of the decision variables that reflect the limited resources of the problem.

In each problem, decision variables, objective functions, and constraint systems are determined, which together form a mathematical model of the real world. One example in linear programming modeling is as follows:

Suppose Z is the total distribution cost and xij (i = 1, 2, . . . , m; j = 1, 2, . . . , n) is the number of units that must be distributed from source i to destination j, then the linear programming formula this problem becomes:

$$\text{Min}\, Z = \sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij}X_{ij} \qquad (1)$$

Fungsi kendala:

Constraint function:

$$\sum_{i=1}^{m} X_{ij} * P_{ij} \leq S_i\,, for\ i = 1, 2, 3, \ldots, 84 \qquad (2)$$

$$\sum_{i=1}^{m} X_{ij} * P_{ij} \geq d_j\,, for\ j = 1, 2, 3, \ldots, 53 \qquad (3)$$

$$X_{ij} \geq 0, \qquad (4)$$

$$integer\ for\ each\ i\ and\ j$$

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Information:
*i* : Source (represents production partner)
*j* : Destination (represents buffer warehouse)
$S_i$ : Supply from source i
$d_j$ : Request on destination j
$C_{ij}$ : Cost per unit distributed from source i
$X_{ij}$ : Number of units distributed from source i
$P_{ij}$ : Possible destination j supplied from source i (binary value 0 or 1)

The above mathematical model can also be described in a table of costs and needs as follows:

Table 1.Table of Costs and Needs

| Cost per unit | | Destination | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | … | *N* | Supply |
| Sources | 1 | $C_{11}$ | $C_{12}$ | … | $C_{1n}$ | $S_1$ |
| | 2 | $C_{21}$ | $C_{22}$ | … | $C_{2n}$ | $S_2$ |
| | . | . | . | … | . | . |
| | . | . | . | … | . | . |
| | . | . | . | … | . | . |
| | *n* | $C_{m1}$ | $C_{m2}$ | … | $C_{mn}$ | $S_m$ |
| Demand | | $d_1$ | $d_2$ | … | $d_n$ | |

Source: Dimyati, 2011

The objective function in this study is shown in equation 1, namely the minimization of distribution costs. In equations 2 and 3 there is X_(ij ) multiplied by P_(ij ) this is because not all objectives j can be met from source i. Especially in the second equation, besides that, it also uses the notation less than because the amount supplied from source i must be less than the capacity of source I. Unlike the second equation, the third equation uses the notation more than equal to, this is because the demand for objective j must be met completely. The number of production partners who are the sources in this study are 86 while the number of destinations that must be supplied is as many as 53 buffer warehouses. Problems whose formulation is still based on the above equation can still be called a linear programming problem. Even if later the formulation of the model made is not exactly the same as the equation above, the formulation is still allowed as long as it is still in accordance with mathematical logic (Lieberman & Frederick, 2001).

## 3. Results and Discussion

### 3.1. Mathematical Model Formulation

The model formulation is carried out to minimize distribution costs, starting with determining the decision variables and then continuing with determining the objective function and the constraint function to determine the optimal distribution allocation of petroganic products.

1. Decision variables are variables that can affect problems in decision making and their values can be controlled by decision makers. Based on this explanation, the decision variable used in this study is the number of products distributed from source I to destination j. The number of products distributed in the study is symbolized by (Xij).
2. The objective function of distribution costs for petroganics from m production partners to n buffer warehouses consists of the freight rate from production partner to i to buffer warehouse to j times the number of goods transported from production partner to i to buffer warehouse to j. Because this research is related to costs, the objective function of this model is minimized.
3. Determine the function of rayon demand constraints and production capacity constraints of production partners. The demand constraint for rayon is the constraint that limits the decision variable on the number of goods transported from production partner to i to buffer warehouse j with the value of buffer warehouse demand, there are 53 buffer warehouses that can get delivery. Production capacity constraints are constraints that limit the decision variable of the number of goods transported from production partner to i to buffer warehouse to j with a production partner capacity value, there are 84 buffer warehouses that can make deliveries.

### 3.2. Determination of Distribution Allocation

Data is processed and formulated into a Linear Programming model, with the help of a computer program solver add-ins to Microsoft Excel. From these results, we can find a solution to determine the optimal distribution allocation from production partners. The presentation of the data is done separately for each week according to the model formulation. Index m shows the number of production partners and

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index n shows the number of buffer warehouses. In the destination function, there is a coefficient C as the product transport rate according to table 2 for the first week.

Table 2. Calculation of Petroganic Distribution Allocation for the First Week

| Xij (Ton) | Buffer Warehouse (j) | | | | | | | | | | | Cost (Rp) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Petrogranik Partner (i) | Jember | Tulungagung 1 | Tulungagung 2 | Bojonegoro | Gresik | Lamongan | Sampang | Tuban | Ngawi | Ponorogo | Malang | |
| 1 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 200 | 0 | 0 |
| 5 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 200 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 300 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | 0 |
| Total Cost | | | | | | | | | | | | 0 |

### 3.3. Validation

The next stage after obtaining the results of the distribution allocation calculation is validation, by checking whether the predetermined limits are met, namely the needs of each buffer warehouse j have been met, not exceeding the capacity of production partner i. The total demand or supply is 21460 tons of petroganic products. The optimization of the allocation of petroganic distribution from production partners to buffer warehouses has changed according to table 4. Overall, to meet the demand from 42 buffer warehouses, petroganic products are sent from 47 buffer warehouses.

Based on the results of the calculation of distribution allocation using the Linear Programming method which is processed with the help of a solver add-ins in Microsoft Excel, it can reduce the distribution costs of petroganic products. The total distribution cost after calculation is Rp. 939,854,960.00. From the calculation of the total initial distribution costs and the calculation of distribution costs based on distribution optimization with linear programming in table 4, it can be seen that there is a decrease in costs. The comparison between the initial cost calculation and the final cost is shown in table 3.

*Table 3. Comparison between Initial Cost Calculation with Final Cost*

| | |
|---|---|
| Initial Cost | Rp1.032.267.660,00 |
| Final Cost | Rp. 939.854.960,00 |
| Decreasing number | Rp92.412.700,00 |
| Decreasing Percentage | 9% |

Based on Table 3, it is known that by allocating distribution with linear programming, it can reduce distribution costs by Rp. 92,412,700,000 or about 9% from Rp. 1,032,267,660.00 to Rp. 939,854,960.00. Optimization of distribution is also marked by a decrease in the number of production partners who meet the needs of 42 buffer warehouses j. In the initial distribution, 56 production partners sent their products, after the calculation process only 47 production partners i sent their products.

### 4. Conclusion

Fulfillment of requests from 42 buffer warehouses j, optimal distribution allocation of petroganic products sent from 47 production partners i. In the first week, 12 production partners of i meet the needs of 11 buffer warehouses j. In the second week, 23 buffer warehouses i fulfill the need for petroganic

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products from 24 buffer warehouses j.
In the

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third week, 21 production partners of i send products to 32 of j's buffer warehouses. Meanwhile in the fourth week, 14 production partners of i sent products to 15 buffer warehouses of j. In the fifth week, 5 production partners of i send petroganic products to 5 buffer warehouses j.

The petroganic partners who made the most deliveries were Metronik Eko Pratiwi, PT with 2000 tons of petroganic products, and Petrosida Gresik, PT (Gresik) with 1300 tons of petroganic products. The Production Partners who deliver the most frequently are partnersfrom Fimaco, CV and K 3 P G who deliver to 4 buffer warehouses with a total shipment of 900 and 840 tons of petroganic products. The buffer warehouse that received the most shipments at the same time was the buffer warehouse Gresik - KIG Block Q, which received shipments of 4300 tons from 7 production partners. Next is the Malang 5 Bakalan buffer warehouse which received 1700 tons from 5 production partners and the Tuban 2 Palang buffer warehouse which received 1220 tons from production partners. On average, production partners made deliveries to 1.77 buffer warehouses, and on average the buffer warehouses received shipments from 1.98 production partners.

Distribution costs after optimization using linear programming is Rp. 939,854,960.00. While the initial cost of distribution is Rp. 1,032,267,660.00. There was a decrease of Rp. 92.412.700.00 or about 9%. Optimization of distribution is also marked by a decrease in the number of production partners who meet the needs of 42 buffer warehouses j. In the initial distribution, 56 production partners sent their products, after the calculation process only 47 production partners i sent their products.

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