Designing production planning optimization model using linear programming method at a coal supply company

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Abstract. A coal supply company in Jakarta that acts as a terminal and a coal processing plant has no production planning method yet, while the demand faced is very volatile. This resulted in the company’s profit to be not optimal. Therefore, it is needed a mathematical model that can be used to make the right production planning so that the company can maximize the company’s profit. Mathematical model is built with Linear Programming method. The objects to be research are fine, nut, and rom coal. The result of this research is obtaining optimum quantity of production from three product types and profit obtained each period in the next 12 periods (May 2018 – April 2019).

1. Introduction

The coal industry in Indonesia began to develop since 1849 when coal resources were discovered in Pengaron, a hamlet along the Mahakam River in East Kalimantan. Since then, so many industries are emerging along with the increase in coal production in Indonesia. It happens because the development of renewable energy sources does not indicate that dependence on fossil fuels will decline significantly in the near future [1]. In addition, Indonesia is predicted to increase coal consumption in the next 20 years [2].

The growth of the coal market has prompted coal supply companies to emerge. One of them is the company where the author conducted this research. The company acts as a coal terminal and coal processing plant. Processing is a process of size reduction of the raw material called asalan to be 3 coal types, i.e. fine (0-20 mm), nut (20-50 mm), and rom (0-50 mm).

Currently, the determination of production quantity in coal supply company is based on intuition and only based on past experience. It happens because the company has no production planning optimization method yet that considers available resources, while the quantity of demand faced is very volatile. This condition makes the way of determining quantity of company’s production becomes inaccurate. It can be seen in the Figure 1, there is a significant gap between demand and supply coal. It makes profit obtained by the company to be not optimal. Therefore, it is needed a mathematical model that can be used to make the right production planning so that the company can maximize profits. In addition, with the mathematical model, the production process can also be done with more efficient utilization of available resources.

In the previous research, there are several research that perform production planning optimization by considering the components of production planning, i.e. research about production planning using Linear Programming where the objective function to maximize profit and decision variable is the amount of each type of LCD produced in LCD manufacturing company [3], research about production planning in petrochemical industry using Mixed Integer Linear Programming with Multi-level Optimization with objective function to maximize company profit and decision variable in the form of production quantity...
of each product type and total production cost from each type of product in every production process [4], and research about production planning at steel company by using Linear Programming, with purpose function maximize profit and decision variable in the form of production tonnage amount of each kind of steel [5].

Based on these three researches, this research will use Linear Programming method to maximize profit by considering to machine operation time availability, raw material availability, minimum production quantity, production target, and warehouse capacity. This model aims to find optimal production planning in the form of production quantity of each type of coal. The result of this research can help companies to cope fluctuations market demand.

![Supply and Demand Coal in 2014–2017](image)

**Figure 1.** Supply and Demand Coal in 2014 – 2017.
Source: Company Annual Report

2. Literature Review

2.1. Production Planning
Production planning is planning of what products and how much will be produced by the company concerned in a period in a future. Production planning is part of operational planning within the company. In the preparation of production planning, need to consider the optimization of production so it can achieve optimal profits and the lowest cost level in production process. Production planning requires products or services demand forecast which are expected provided by company in the future. Thus, forecasting is an integral part of production planning [6].

2.2. Forecasting
Forecasting is art and science of making projections about future demand [7]. Forecasting has four main characteristics [8]. These characteristics are as follows:

1. Forecasting are usually wrong.
2. Every forecast should include an estimate of error.
3. Forecast are more accurate for families or groups.
4. Forecasts are more accurate for nearer time periods.

2.3. Time Series Analysis
Forecasting using time series is based on future estimates conducted using time as the basis for forecasting. This method assumes that what has happened in the past will happen in the future. An important step in choosing an appropriate time series method is to consider the type of data pattern. The pattern of data can be divided into 4 types, trend (has a tendency to rise or fall), cycle (has a periodic cycle), seasonal (influenced by seasonal factors), and random (no particular pattern).
The methods included in time series analysis and used in this study include moving averages, single exponential smoothing, double exponential smoothing, holt's winter, and decomposition.

2.4. Linear Programming
Linear Programming (LP) is used for model optimization in which the objective function and constraint functions are linear [9]. The linear program also very efficiently calculates algorithms for problems with thousands of constraints and variables. Linear Programming has three elements, namely:
1. Decision variable, is solution sought by the model and meet all existing constrains.
2. Objective function, is the function to be optimized in the search solution. Optimization of solutions can be done by maximizing or minimizing.
3. Constraint, is an equation or an inequality that limits the value of a variable.

3. Research Methodology

3.1. Data Collection
This research is conducted by taking case study at one of coal supply company, it is PT. Maju Bersama Sejahtera and seek the problems that exist in the production process. The method used in completing this research is linear programming method. The required data are historical data, including gross profit data, demand data, minimum production quantity, data of machine operation time and machine speed, and raw material inventory data of coal.

3.2. Linear Programming Methodology
Data processing in this research begins with identifying objective functions and constrains, which is served in Figure 2. Secondly, forecasting demand in the next 12 periods that will be used as a limit of production targets. Then design a mathematical model consisting of objective function and constraint function. After the mathematical model is complete, then verification and validation of the model using LINGO 17.0 software.

This production planning model is designed based on 3 journals as reference, i.e. journal by Al-Kuhali, Zain, & Hussein (2012), Kadambur & Kotecha (2016), and Supriyadi (2017) with additional variables and constraints required and in accordance with condition of company. This horizon is divided into several periods (i.e. months), cost are considered fixed for all periods, remaining raw material at the end of the period are ignored, and labor is not considered.

Index:
i = machine type (1=1,2)
j = coal type (j = 1,2,3)
k = period (k=1,2,...,n)

Parameters:
$C_j$ profit for coal production type j
$a_{ij}$ time needed for machine i to produce 1 ton of coal type j
$Y_k$ total of machine operating time available in period k
$d_j$ amount of raw material usage for coal type j
$K_k$ raw materials available in period k
$R_{jk}$ quantity of demand (production target) for coal type j period k
$B_j$ minimum production quantity for coal type j
$M$ warehouse capacity

Decision variable:
$X_{jk}$ optimal production quantity for coal type j period k
3.3. Forecasting Demand

Demand forecast using historical demand data in January 2014 - April 2018 (52 periods). This forecast is conducted to see demand quantity for each type coal in the next 12 periods (period 53 - period 64). By looking at the pattern of data trends, the pattern of fine, nut, and rom demand is seasonal, then selected time series analysis i.e. Holt’s Winters, Single Exponential Smoothing, Double Exponential Smoothing, Moving Average and Decomposition are selected. Comparison of forecasting errors in each method is shown in Table 1 and in Table 2 is the result of forecasting demand in the next 12 periods.

The best forecasting method is the method with the smallest MAPE value. Thus, the preferred forecasting method for fine coal is Winters method with MAPE = 12%, forecasting method for nut coal is Winters method with MAPE = 14%, and forecasting method for rom type coal is decomposition method with MAPE = 23%.

| Method                         | MAPE (%) |
|--------------------------------|----------|
|                                | Fine     | Nut     | Rom     |
| Winters                        | 12       | 12      | 24      |
| Single Exponential Smoothing   | 25       | 23      | 37      |
| Double Exponential Smoothing   | 26       | 23      | 36      |
| Moving Average                 | 14       | 18      | 38      |
| Decomposition                  | 19       | 26      | 23      |

3.4. Model Verification and Validation

The last step of methodology is model verification and validation. Verification is done by translating mathematical model to software LINGO 17.0, then the software is run and seen if there is error in it. If the model that has been created in LINGO does not have an error and displays the result of a decision variable value, then the model has been verified. In Figure 3 it is seen that the results obtained are Global Optimum and there is no error in it, so it can be said that the model has been verified.
Model validation is done by reviewing the constraint function that has been made and to test the sensitivity [10]. From the validation process, shown that the results obtained in accordance with the constraints function and changes in parameters resulted in a rational output change, so it can be said that the model has been valid.

Figure 3. Lingo Solver Status for Model Verification.

4. Result and Discussion
The mathematical model that has been created and verified and validated is then used to find the solution of the problem in this research by using LINGO 17.0 software. Computation process using historical data from company that have been described before. After all formulations and data are entered into the LINGO 17.0, then the results obtained that can be seen in Table 3.
Table 3. Result of Optimal Coal Production Planning.

| Period | Fine (Ton) | Nut (Ton) | Rom (Ton) | Gross Profit |
|--------|-----------|-----------|-----------|--------------|
| 53     | 3481.28   | 2787.08   | 1242.83   | Rp 119,640,690 |
| 54     | 1729.22   | 2117.98   | 1080.24   | Rp 81,043,060   |
| 55     | 4312.92   | 3180.01   | 1133.2    | Rp 136,666,160  |
| 56     | 4373.16   | 3360      | 1940.89   | Rp 153,164,430  |
| 57     | 3970.59   | 3040      | 1515.57   | Rp 135,151,220  |
| 58     | 4662.07   | 3680      | 1321.74   | Rp 154,033,010  |
| 59     | 5040      | 3360      | 1597.49   | Rp 156,682,350  |
| 60     | 4458.95   | 3040      | 1716.37   | Rp 144,511,900  |
| 61     | 4625.51   | 3520      | 1922.73   | Rp 159,372,580  |
| 62     | 4560      | 3040      | 1551.23   | Rp 143,348,450  |
| 63     | 4410.83   | 3200      | 912.2     | Rp 135,023,790  |
| 64     | 4800      | 3200      | 1412.78   | Rp 147,591,700  |

Quantity planning of each type of coal produced can be produced using available resources. The largest amount of production is the fine coal 4800 tons in period 64. While the least amount of production is rom coal 912.2 tons produced in period 63, all products can be produced without the lack of available resources. Therefore, it can be argued that with planning that has been designed based on optimization results with mathematical models that have been made to meet all the existing demand and generate maximum profit for the company.

In addition, also seen the amount of gross profit earned per period. Periods that have the largest and smallest total profits respectively are period 61 with total profit of 159,372,580 rupiahs and 54 periods with total profit of 81,043,060 rupiahs. Amount of profits are influenced by the coal production quantity.

Then, a business scenario analysis is performed. First, analysis is done by changing in raw material availability parameters, namely the decrease of 1 barge (7500 tons), the addition of 2 barges and the addition of 3 barges, while other parameters remain. From this result obtained that the effect of changes in the availability of raw materials to profit is 8.71%.

The second stage is done by changing in available machine operating time parameters, i.e. decrease of 15%, 10%, 5% and increase of 5%, 10%, 15%, while other parameters are fixed. From this result obtained that the effect of changes in available machine operating time to profit is 31.76%.

The third stage of analysis is done by changing in production targets quantity parameters, i.e. decrease of 15%, 10%, 5% and increase of 5%, 10%, 15%, and other parameters are fixed. From this result obtained that the influence of production target quantity to profit is 69.02%.

5. Conclusion
Based on data collection, data processing, and analysis of results that have been done related to the optimization of production planning at coal provider companies, obtained some conclusions obtained from this research:

1. A model of production planning problem solving for coal product case has been obtained.
2. The output generated after running the optimization model is the production quantity planning for each type of coal within the next 12 months (May 2018 - April 2019) along with the profit gained each month.
3. The quantity of production produced from the Linear Programming model shows that the quantity of production is obtained close to the value of production targets obtained from demand forecasting by considering the availability of resources. This ultimately results in maximum profit.
4. The most heavily produced coal type is fine coal with an average of 4202.04 tons per period and the least is the rom type coal with an average of 1445.61 tons per period.
5. Based on the sensitivity analysis, it was found that the production target (total demand) had a significant effect on the profit increase, that is equal to 69.02%, followed by the parameters of the availability of the machine operating time amounted to equal to 31.76% and the raw material availability parameter is equal to 8.71%.

6. Based on the results of sensitivity analysis in this research obtained recommendations for the company that is if the company want to increase profits, the company can increase production targets and increase time machine operation available.

7. For future research related to the development of this research, author gives some suggestions, the first is to add other factors of production in the developed model, such as the remaining raw materials at the end of the period and the labor that has not been included in this research, and the second is to incorporate more specific benefit components in the developed model, such as sales prices and production costs that have not been specifically addressed in this research.

6. References
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