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PLANNING AND CONTROLLING INVENTORY OF COAL USING MODEL PROBABILISTIC Q BACKORDERWITH CONSIDER OF STORAGE CAPACITY

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Abstract *Inventory of fuel is very important in the production process, because the fuel is one factor that ensures smooth production process. The Industry's sector is a company engaged in provision power and steam with the coal. On determining amount of the current inventory of coal in The Industry's sectorstill fluctuating from storage capacity, so it is necessary to study the planning and controlling inventory of coal with consider of storage capacity. This study aims to optimize the amount of the coal fuel, determine reorder point, determine safety stock and determine total cost of inventory using inventory probabilistik Q model backorder storage capacity constrain. Data processing results obtained optimal order for each the coal is as much as 11.000 tons, Reorder point is as much as 607,346 tons, safety stock is as much as 1,292 tons and total cost of inventory is as much as Rp. 16.052.531.575 using inventory probabilistik Q model backorder storage capacity constrain.*

Keywords : *Inventory Control, Probabilistik Q Model, Q Optimal, Reorder point, Safety Stock*

1. Introduction

Inventories of raw materials is very important because the raw materials are materials that will help the process of production. Raw material inventory planning is intended to meet the needs of raw materials for the production process in the future and raw material inventory control activities regulate the procurement of raw materials necessary to the amount needed and at minimum costs.

The Industry's sector is a company engaged in the supply of power and steam which will then be distributed to the paper mill PT. IKPP to the production process of paper making. To carry out the process of providing the energy source, the company requires a supply of fuel. The fuel used to generate steam at the industry's sector is coal. In determining the amount of fuel supply coal at *The Industry's sector* is still fluctuated from warehouse capacity available, because the number of bookings based on the average usage of coal prior period used as a benchmark company. So it is necessary to study the planning and inventory control one fuel at *The Industry's sector*, namely coal by considering the capacity of the warehouse in order to get the amount of inventory and optimal total cost of inventory [1].

This research aims to optimize the amount of coal ordering, specify the reorder point, determine the value of safety stock and calculate the total cost of inventory using probabilistic inventory models Q back order considering the capacity of the warehouse.

The method used in this research is to determine the approximate amount of fuel supplies coal to The Industry's sector is optimal to perform the method of forecasting to estimate the amount of demand in the coming period based on the number of requests in the previous period. As for inventory control using a probabilistic model Q which in principle is a further development of a probabilistic model is simple [2], the number of requests in the previous period is not certainty known and the booking is made based on the lot size ordering (qo) and the reorder point (r) is fixed in accordance with the existing inventory.

2. Research Methodology

In this study, the first thing to do is to forecast using three methods: Moving Average, Double Exponential Smoothing and ARIMA in which these three methods used for data patterned stationary. Moving average method is implemented using the equation 1: [3]

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Where:

$$M_t = \hat{Y}_{t+1} = \frac{(Y_t + Y_{t-1} + \ldots + Y_{t-n+1})}{n} \quad (1)$$

$\hat{Y}_{t+1}$ = *Forecast for periodet + 1*
$\hat{Y}_t$ = *Data for period t*
n = *Time PeriodMoving Averages*
The value of n is the number of periods in the moving average.

The second forecasting methods is Arima model. Arima Model is model that fully ignores the independent variable to make a prediction [4]. Arima use the past and present dependent value to predict the value in the future accurately. Arima cab be applied if time series observation statistically connected to each other (dependent) [5]. Arima model is used in the study was ARIMA conducted in four phases:

1. Phase Identification
   Phase identification is done by observing kestasioneran data can be seen visually through a time series plot, the pattern of the estimated autocorrelation function (ACF), the pattern of the partial autocorrelation function (PACF).
2. Phase Estimation Parameters
   In general ARIMA model parameter estimation using several methods: Moment method, the method of Least Squares and Maximum Likelihood.
3. Phase Diagnostic
   Diagnostic studies can be divided into two parts: parameter significance test and conformance test.
4. Phase Forecast
   Stage Forecasting can be done if all significant model parameters and the entire residual assumptions are met

The third forecasting methods used in the research is the Double Exponential Smoothing implemented using the equation:[3]

$$S'_t = \alpha\, d_t + (1-\alpha)\, S'_{t-1} \quad (2)$$

$$S''_t = \alpha\, S'_t + (1-\alpha)\, S''_{t-1} \quad (3)$$

$$a_t = S'_t + (S'_t - S''_t) = 2\, S_t' - S_t'' \quad (4)$$

$$bt = \frac{\alpha}{1-\alpha}(S' t - S'' t) \quad (5)$$

$$S_{t+m} = a_t + b_t \,.\, m \quad (6)$$

Where :
d_t = The actual data in period
S'_t = The value of*single exponential smoothing*
S''_t = The value of*double exponential smoothing*
α = Constant Income
a_t = The correction factor on the pattern of forecasting
b_t = The correction factor
m = The number of periods to be foreseen in the future
S_{t+m} = Forecasting for future periods m from t

After forecasting using two methods of forecasting time series we conducted measurements of the level of error in forecasting by calculating the MSE, MAPE, MAD and Tracking Signal [3]. After testing the error rate of data demand is there then the next is to perform the calculation of fuel supply coal to the data using current demand forecasting elected for 2016. Calculation of this raw material inventories using the first involved with probabilistic inventory models without constraints (Model (Q , r)) with Back Order Policy [6]. Where in the solution using the equations that are calculated simultaneously through several iterations with counting procedures as follows: [7]

a. q_1* Calculated using the formula Wilson:

$$q_1^* = \sqrt{\frac{2\ x\ A\ x\ D}{h}} \quad (7)$$

b. α andr_1* Calculated using the following equation:

$$\alpha = \frac{hq_1*}{CuD} \quad (8)$$

after obtaining the value of α, then look for the value Zα using Table Possible Disadvantages to get a reorder point and safety stock:

$$r_1^* = D_L + Z_\alpha S\sqrt{L} \quad (9)$$

$$ss = Z_\alpha S\sqrt{L} \quad (10)$$

c. q_2* Calculated using the following equation:

$$q_2^* = \sqrt{\frac{2D[A + Cu\int_{r1}^{\infty}(x-r)f(x)dx]}{h}} \quad (11)$$

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$$N = \int_{r1}^{\infty} (x - r) f(x) dx = S_L [f(Z_\alpha) - Z_\alpha \psi(Z_\alpha) \quad (12)$$

d. Recalculating α and r_2*using the following equation:

$$\alpha = \frac{hq2*}{CuD} \quad (13)$$

e. Continue this event to a value equal to the value q_2*r_2* so the value towards a certain price that has not changed, meaning toward convergent. Thus obtained q_1* and the optimal r_1*.

After performing calculations using probabilistic inventory models without constraints (Model (Q, r)) with Back Order Policy. The next step is to perform calculations using probabilistic inventory models with constraints (Model (Q, r, λ)) [6]. The constraint functions used are capacity constraints warehouse. Where the solution is using the multiple equation: [8]

a. q_1* Calculated using the following equation:

$$q_1* = \sqrt{\frac{2D[A + Cu \int_{r1}^{\infty} (x-r) f(x) dx]}{h + 2\lambda.1}} \quad (14)$$

Q1 * value obtained by first finding the value of λ by trial and error. The value λ that meets the solution is at which time the value of λ is used to produce optimum quantity does not exceed the capacity of the storage warehouse [9].

b. α andr_2* Calculated using the following equation:

$$\alpha = \frac{hq2*}{CuD} \quad (15)$$

after obtaining the value of α, then look for the value Zα using Table Possible Disadvantages to get a reorder point and safety stock:

$$r_1* = D_L + Z_\alpha S\sqrt{L} \quad (16)$$

$$ss = Z_\alpha S\sqrt{L} \quad (17)$$

Where :

q_1* = Optimal number of reservations

A = Ordering Cost

D = Demand

Cu = S*hortage*Cost

N = Expected*shortage*

h = Holding Cost

λ = Lagrangian multiplier

ki = Volume

ss = *safety stock*

After getting the value of optimal order quantity, reorder point and safety stock, the calculation for the costs of the total cost of inventory:

$$OT = \frac{AxD}{qi^*} + h\left(\frac{qi^*}{2} + r - D_L\right) + \frac{Cu\ x\ D}{qi^*} \int_r^{\infty} (x - r f x dx \quad (18)$$

3. Result and Analyze

3.1 Forecasting Coal Supplies

Forecasting is used to determine how much coal demand expectations for 2016. The data used to forecast is past data for the years 2013, 2014 and 2015 with the average number of requests per year is 31.612 tons and the average number of requests per month is 2.634,3 Ton.

Criteria for Performance Forecasting used method is to use MAD (Mean Absolute Deviation) is the average - average error absolute during certain periods of whether forecasting results is greater or smaller than the actual data, MSE (Mean Squared Error) is summing the squares of all the errors of forecasting at each period and dividing by the number of forecast period, MAPE (Mean Absolute percentage error) which states the percentage of errors in the results of forecasting the demand for actual during a certain period and TS (Tracking signal) is measuring that if the value of the tracking signal has been located outside the boundaries of control, the model the forecasting needs to be revisited, because the accuracy of forecasting cannot be accepted [10]. And if the tracking signal are within control limits of the calculation can be used or continued [11].

From the graph above plots Figure 1, note that these data indicate that the data pattern fluctuated ride - down and were around the average - average, it can be said that the data

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pattern is stationary but the plot data also contain the trend in the mid-term, so that the forecasting method looking for patterns of such data is the moving average, ARIMA and Double Exponential Smoothing [12].

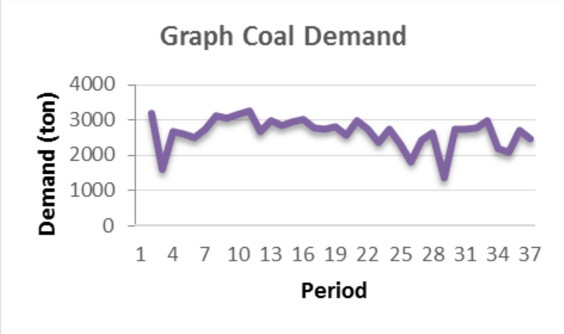

Fig. 1 Graph coal demand

The first forecasting methods used Moving Average using the value of N which is the number of periods in the moving average, because the pattern of historical chart data is fluctuating but not too volatile, the small values of N would be more suitable, namely 3 and 4. The second method is the method of Autoregressive Integrated Moving Average (ARIMA) in which the data processing has modeled Moving Average (MA) and Autoregreesive (AR), because at the time of the identification of patterns ACF (Autocorrelation Function) and PACF (Partial Autocorrelation Function) shows the graph is Cut Off , The third method is a method used in forecasting Double Exponential Smoothing. This method is a result of the development of the Single exponential smoothing. Exsponential double smoothing method capable of processing data in the form as a pattern trend. Double exponential smoothing method may be calculated by requiring three data values and the value of α. A value used is 0.1; 0.5 and 0.9 [13].

Selection of the best forecasting method to be used for coal demand by comparing the error rate using MSE [14]. MAPE, MAD happens in each forecasting method.

Based on the results obtained data processing methods ARIMA AR model that has the smallest error in comparison with other methods so that the AR model ARIMA method is the best method used for forecasting demand for coal in 2016 with total demand amounting to 31.601,4 Ton and the average - average number of requests per month is 2.633,45 Ton.

Table 1. Values Error Results Forecasting

	MAPE	**MSE**	**MAD**
***Single Moving Average* (N = 3)**	0,2399	441,8528	405.908,7551
***Single Moving Average* (N = 4)**	0,2497	464,2833	424.948,4554
ARIMA Model MA	0,1866	343,9444	246.748,7991
ARIMA Model AR*)	0,1861	342,9241	245.940,2814
***Double Exponential Smoothing* (α = 0,1)**	0,2259	412,9658	367.437,1890
***Double Exponential Smoothing* (α = 0,5)**	0,2097	386,1813	317.140,4986
***Double Exponential Smoothing* (α = 0,9)**	0,2146	425,2183	293.450,7601

*) The Best Forecast Method

Table 2. Forecasting Result

Period	**X**
1	2610,172376
2	2632,210647
3	2635,417075
4	2635,88359
5	2635,951465
6	2635,961341
7	2635,962777
8	2635,962987
9	2635,963017
10	2635,963021
11	2635,963022
12	2635,963022
Total	**31.601,4**

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3.2 Inventory Probabilistic Models

Probabilistic inventory model is characterized by the behavior of the demand and lead time which can not be certainty known in advance it needs to be approached with a probability distribution. The condition causes the need for inventory with the uncertainty of reserves to dampen fluctuations for a certain time. With the safety stock, then there will be additional costs in the additional inventory storage. This model uses the basic formula of EOQ, but coupled with optimal safety stock calculations taking into account variations in demand during the lead time so that the minimum costs incurred. The amount of reserves that is set at the maximum demand is reduced by an average demand, this means to determine the reserves that must be known how much the maximum demand. [15].

In probabilistic inventory, maximum demand is uncertain but is not probabilsitic and will be represented by the standard deviation. Thus it will not be easy to determine the amount of the safety recommendations. The simplest approach to solve the problem is with the Nuclear probabilistic considers that the inventories on static deterministic inventory system by adding a safety recommendation (ss) to anticipate and mitigate fluctuations in demand [16].

Basically inventory model calculation uses the purchase price, booking fees, costs and cost savings, and supply shortages. Inventory model in this study using probabilistic inventory models Q for the number of coal demand in the coming period is not known with certainty and the booking is made based on the number once the booking is fixed (qo) and the value reorder point (r).

1. Number of Optimal Order
   The calculation process consider the capacity warehouse inventory model is identical to the calculation of inventory model without constraints. To determine the number of bookings is optimal in this study, the first to perform calculations using the model probabilistic inventory without constraints, from the calculations have been carried out showed that the results do not meet the existing constraints or in other words the result of calculating the number of reservations optimal exceeds the storage capacity is equal to 11.030,23 Tons, then the subsequent calculation of the optimal order quantity by using a probabilistic model supply constraints. Calculation models probabilistic inventory constraints Q is done by finding a value λ, where λ is the unknown parameter known as the multiplier lagrange. value λ in the calculation of the number of bookings optimal order quantity sought by trial and error until the results of the calculation of the number of optimal order quantity obtained meet the existing constraints, where the constraint is used warehouse storage capacity is available for coal fuel.
   From the calculation, the number of optimal order by using a probabilistic model supply constraints λ value obtained for coal fuel is λ = 693,5. So that the optimal value of the number of bookings for fuel amounted to 11.000 tons of coal. Based on the optimal number of bookings from berkendala probabilistic inventory model, known frequency bookings were made 3 times in one year. While the number of bookings made on the company's policy of ± 8.000 tons, so the frequency of bookings made as many as four times in one year. In this case, the frequency of ordering constraints probabilistic inventory models smaller than the frequency of the reservation policy of the company, so the company can save money booking done because it will affect the total cost of inventory for 2016.
2. *Reorder Point*
   Reorder point is a situation where the raw materials that are in a certain amount require that the company will book back to maintain the sustainability of the production process. From the results of model calculations using the model fuel supply constraints probabilitsik (Q, r, λ) with "backorders policy" then obtained reorder quantity (reorder point) for coal fuel amounted to 607,346 tons. Number reorder point obtained from the results of this calculation is affected by the amount of safety stock which is the amount of fuel needed by the company in anticipation of fuel supply so that production is not interrupted when the fuel is ordered not to or could not be used to process and is also

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affected by the number of average - average fuel demand during the lead time.

3. *Safety Stock*
From the calculation of raw material inventory planning using a probabilistic model supply constraints (Q, r, λ) with "backorders policy" so he found the amount of reserves (safety stock) for coal fuel that is 1,292 tons. The amount of safety stock obtained from the results of this calculation is affected by the standard deviation of fuel demand and the company's service level (z). Standard deviation is the value of the standard deviation around the average demand during the average - average lead time or an approximate value of the likelihood of different requests with the average - average demand, while the value z is a factor of the level of service of the company. Based on the results of forecasting demand for coal, the standard deviation of demand for coal in 2016 amounted to 7,41 tons, due to a small standard deviation value which may affect the value of safety stock is small. It is the standard deviation is proportional to the value of safety stock.
4. Inventory control using probabilistic inventory model is restricted (Q, r, λ) with "backorders policy" on the company showed better results compared with the planning done by the previous company. It can be seen from the calculation results obtained optimal order quantity (Q), reorder point (r) and safety stock (SS) is optimal. In addition to the calculation of the total cost of which was found between the calculations using probabilistic inventory model is restricted (Q, r, λ) with "backorders policy" is smaller than the calculation of the total cost of inventory is based on the company's policy. Total cost incurred using probabilistic inventory model is restricted (Q, r, λ) with "backorders policy" of Rp. 16.,052.531.575 per year, while the total cost of inventory is based on the company's policy of Rp. 17.230.443.988 per year. The difference between the total cost of inventory probabilistic model is restricted (Q, r, λ) with "backorders policy" with a total cost of inventory is based on the company's policy of Rp. 1.177.912.412 percentage savings of 6,84%. The difference in the total cost is influenced by the number of orders, reorder point and safety stock which causes a different frequency booking, reservation frequency of probabilistic inventory model is restricted smaller than frequency ordering of company policy, so that companies can save the cost of bookings made. Therefore, the optimization method can be used as input to the PPIC in *The Industry's sector* to supply coal to the optimum.

5. Conclusion

Based on calculations that have been done in the planning of coal supplies can be concluded that the optimal amount of coal that must be ordered in one order using a probabilistic model Q back order by capacity constraints storage warehouse is 11.000 tons. Reorder point (reorder point) is 607,346 tons of coal inventory. Reserves that must be provided in order to anticipate fuel shortages of coal amounted to 1,292 tonnes. And the total cost of inventory acquired for 2016 amounting to Rp. 16.052.531.575 per year.

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