Analysis of Raw Material Inventory Planning Considering Uncertainty Demands (Case Study: Model Q with Back Order at PT. X)

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Abstract. In the production process a variety of products owned by PT. X are very high because the company does not have the same product to make every day. In the delivery of raw materials by suppliers there is also a delay in delivery caused by the empty stock of raw materials at the supplier and also the pre-order purchasing system. Problems with PT. X are planning demand and raw material inventory by considering demand uncertainly. As a first step in choosing the right inventory policy method, the Kolmogorov-Smirnov Test for normality test and ADI (Average Demand Interval) test are the classification of raw materials based on demand patterns. Of the five types of raw materials, the ADI value is 0, 91 and 1, which means < 1, 32. So that the completion of raw material inventory planning is done by probabilistic inventory policy method Continuous Review (Q) Back Order with Hadley -Within algorithm. The results of data processing are known to be the level of service of each type of raw material with the calculation of the proposed method, the average value of the service level for the five types of raw materials studied reaches 99, 30%. Where the probabilistic method of the Continuous Review System (Q) Hadley-Within algorithm, provides savings of 7,75% of the total cost of the existing inventory of the company.

1. Introduction
Inventory is one of the most important elements in the production process.[1] Inventories are resources that are stored and used to meet current and future needs so that all activities can run according to what is planned and expected. In the case of inventory being stored in a warehouse for too long will result in damage and high embedded costs. If the inventory is lacking, the company cannot meet customer demand resulting in lost profits. In addition, the instability of demand also affects inventory in the company. Safety stock is an additional inventory to maintain the possibility of shortages (stock out) [7] Inaccurate number of orders specified is caused because the company only considers the results of forecasting needs, safety stock, and ending inventory in determining the order amount. In determining the number of orders, the company never considers the uncertainty factors that come from suppliers. Whereas in the real inventory system in addition to the uncertainty that comes from
forecasting demand, uncertainty that comes from suppliers also affects the inventory system. Therefore, the inventory policy system must be well planned by the company. This study will discuss the planning of demand and supply of raw materials by considering demand uncertainty. The purpose of this research is to plan raw material demand for the next period and plan raw material inventory that determines the order lot size, the optimal level of service and the total costs incurred by the company in producing finished goods.[16]

2. Literature Review

2.1 Forecasting
Forecasting is art and science for estimate future events. This can be done with involves taking past data and placing it into the future come with a form of mathematical model. Serial Time Model Forecasting Method [15].

2.2 Probabilistic Inventory Model Q
According to [7] the Q model / method solves the problem probabilistic inventory by looking at the position of the goods available at warehouse is equal to the position of inventory in a deterministic system added by safety stock. In this Q model every time an order is made in the same number of lot orders and orders made if the inventory has reached the reorder point.

2.3 Formulation of Model Q
The following is the formulation of Q model for inventory costs namely:[10]

- Cost of Purchase (O_b) The cost of buying goods is a multiplication between the expectations of the amount goods purchased (D) with the price of the item per unit (p), accordingly mathematically written as follows: $O_b = D \cdot p$. (1)
- Procurement Costs (O_p) The cost of procurement per year depends on the amount of expectations order frequency (f) and fees for each time you do it order (A). Systematically, procurement costs can be stated as follows: $O_p = f \cdot A$. (2) The amount of frequency of ordering per year depends on expectation needs per year (D) and the size of the ordering lot (q_0), it is stated as follows:
  \[ f = \frac{D}{q_0} \] (3)
  So, the cost of procurement per year is obtained, namely: $O_p = \frac{AD}{q_0}$. (4)
- Cost of Save (O_s) Save per year depends on the expectations of inventory which is saved (m) and the cost of savings per unit per year (h), which can stated as follows: $O_s = h \cdot m$ ……………… (5)
  The cost of storing per unit per year (h) is usually a function of the price of goods stored and the amount expressed as a percentage (I) of the price of goods (p).
  \[ h = I \cdot p \] (6)
  The amount of inventory stored (m) is the number of items that are in warehouse (s) and after the order comes the number of items will be equal to (s + q_0). Thus the inventory steady state exists inside warehouse will fluctuate between s and (s + q_0), so expectation existing inventory (m), namely:
  \[ m = \frac{1}{2} q_0 + s \] (7)
  So, the save cost is:
  $O_s = \left(\frac{1}{2} q_0 + s\right) h$ ……………… (8)
- Cost of Shortage of Inventory (O_k) The cost of inventory shortages can be based on the quantity of goods which is lacking. If the cost of deficiencies per unit of goods is π, the cost annual inventory shortages are:
  $O_k = N T C_u$. ……………… (9)
Where: $N_T$: The number of shortages of goods for one year, $C_u$: Cost of inventory deficiencies per unit of goods (Rp/unit). The price of $N_T$ can be calculated with the expectation of the amount of inventory deficiencies each cycle ($N$) and the expected cycle frequency for one year ($f$), that is:

$$N_T = f \cdot N$$  \hspace{1cm} (10)

Where: $f = \frac{D}{q_0}$ and $N = \int_{r}^{\infty} (x - r) \, dx$, Thus the cost of inventory deficiencies is:

$$O_k = \frac{C_u D}{q_0} \int_{r}^{\infty} (x - r) \, dx$$  \hspace{1cm} (11)

### 2.4 Model Q with Back Order

The following model formulations and solutions are only valid if inventory shortages are treated by way of back order. In terms of this user wants to wait for the item requested to arrive at available in the warehouse.

#### 2.4.1 Model Formulation and Solutions

Results obtained from substitution into $O_T$. If it’s lacking inventory is treated by way of back order will be obtained:

$$O_T = O_b + O_p + O_s + O_k$$  \hspace{1cm} (12)

$$O_T = Dp + \frac{AD}{q_0} + hL + C_u \int_{r}^{\infty} (x - r) f(x) \, dx$$  \hspace{1cm} (13)

To find the optimal decision variable value $q_0$, $r$ and $s$ are obtained by using the principle of optimization, namely by utilizing properties $O_T$ convection of $q_0$ and $r$.

Thus the condition that $O_T$ minimal is:

i) $h q_0^2 = 2AD + 2C_u \int_{r}^{\infty} f(x) \, dx$ \hspace{1cm} (14)

ii) $h \cdot 2D [A + C_u \int_{r}^{\infty} f(x) \, dx] = h q_0$ \hspace{1cm} (15)

#### 2.4.2 Solution to the Hadley – Within Method

To determine the value of $q_0^*$ and $r_1^*$ iteratively searched.

a) Calculate the ordering lot ($q_0^*$) with the Wilson formula explained with calculation below:

$$q_0^* = \sqrt{\frac{2AD}{h}}$$  \hspace{1cm} (16)

b) Based on value $q_0^*$ obtained can be searched for magnitude possible lack of inventory.

$$\alpha = \frac{h q_0^*}{C_u D}$$  \hspace{1cm} (17)

$$\alpha = \int_{r}^{\infty} f(x) \, dx \text{ where, } r_1^* = D_L + z_{\alpha} S\sqrt{L}$$  \hspace{1cm} (18)

c) By knowing $r_1^*$ the $q_0^*$ value will be calculated with the formula as follows:

$$q_0^* = \sqrt{\frac{2D [A + C_u \int_{r_1^*}^{\infty} f(x) \, dx]}{h}}$$ \hspace{1cm} (19)

Where: $\alpha = \frac{h q_0^*}{C_u D} \int_{r}^{\infty} f(x) \, dx = S_L [f(z_{\alpha}) - z_{\alpha} \Psi(z_{\alpha})]$

Values $f(z_{\alpha})$ and $\Psi(z_{\alpha})$ can be found from the table.

d) Calculate again the value of $\alpha = \frac{h q_0^*}{C_u D}$ and $r_2^*$ value with use:

$$\int_{r_2}^{\infty} f(x) \, dx \text{ Where, } r_2^* = D_L + z_{\alpha} S\sqrt{L}$$  \hspace{1cm} (20)
e) Compare the value of \( r_1^* \) and \( r_2^* \); if the price is \( r_2^* \) relative to \( r_1^* \) the iteration is complete and will be obtained \( r^* = r_2^* \) and \( q_0^* = q_{02}^* \). If not, go back to step c by replacing the value \( r_1^* = r_2^* \) and \( q_0^* = q_{02}^* \).

3. Methodology
Demand planning it is processed with using forecasting methods that get the smallest error value.[5] While, for inventory planning is done with the Q model with a back order. For Inventory planning has processing stages, namely: calculating forecasting request, test data normality, perform ADI analysis (Average Demand Interval) and calculate inventory planning using the Q back order model by doing iterations to get optimal results. Then that the last is the stage of analysis and conclusions from the research conducted and suggestions that can be proposed.[11]

4. Result
Data Collection
4.1 Data on the Use of Raw Materials in 2018
Raw material demand data taken based on calculations use of raw materials for each product and calculated by the number of results product sales from January - December 2018 using raw materials of dinir, satin, folyfoam, bisban and canvas.

4.2 Cost Data
Cost data used are costs associated with inventory planning calculation. Such as saving costs (h), costs order  (A), cost of deficiency (Cu) and price of raw materials (p). Cost this fee is obtained based on the results of interviews with the general manager PT. X.

| Raw Material | Price (p)  | Order cost (A) | Saving cost (h) | Cost of deficiency (Cu) |
|--------------|------------|----------------|-----------------|-------------------------|
| Dinir        | Rp 15.000  | Rp 50.000      | Rp 1.500        | Rp 50.000               |
| Satin        | Rp 12.000  | Rp 50.000      | Rp 1.200        | Rp 50.000               |
| Folyfoam     | Rp 15.000  | Rp 50.000      | Rp 1.500        | Rp 50.000               |
| Bisban       | Rp 3.500   | Rp 50.000      | Rp 350          | Rp 50.000               |
| Kanvas       | Rp 32.000  | Rp 50.000      | Rp 3.200        | Rp 50.000               |

4.3 Demand Forecasting
Demand forecasting is done using 2018 data for planning demand next year. Forecasting is done with the Naive method, Single Moving Average 2 and 3 periods and Single Exponential Smoothing alpha (α) 0.1 and 0.5. Then get results raw material demand forecasting / planning in 2019 in table 2.

| Month       | Dinir | Satin | Folyfoam | Bisban | Kanvas |
|-------------|-------|-------|----------|--------|--------|
| January     | 340   | 530   | 247.33   | 855    | 180    |
| February    | 342.5 | 532.5 | 253.11   | 897.5  | 186.67 |
| March       | 341.25| 531.25| 252.15   | 876.25 | 185.56 |
| April       | 341.88| 531.88| 250.86   | 886.88 | 184.08 |
| Mei         | 341.57| 531.57| 252.04   | 881.57 | 185.44 |
| June        | 341.73| 531.73| 251.68   | 884.23 | 185.03 |
| July        | 341.65| 531.65| 251.53   | 882.9  | 184.85 |
| Agusts      | 341.69| 531.69| 251.75   | 883.57 | 185.11 |
| Sept        | 341.67| 531.67| 251.65   | 883.24 | 185    |
| Oct         | 341.68| 531.68| 251.64   | 883.41 | 184.99 |
| Nov         | 341.68| 531.68| 251.68   | 883.33 | 185.03 |
| Des         | 341.68| 531.68| 251.66   | 883.37 | 185    |
Total 4100m² 6380m² 3020m² 10890m² 2220m²

4.4 Data Normality Test
The following is a hypothesis that is tested against data on each type of raw material:
H₀: Request data is normally distributed
H₁: Request data is not normally distributed
The reference to accepting or rejecting the hypothesis is:
If Sig. (P) > 0.05 then H₀ accepted
If Sig. (P) < 0.05 then H₀ is rejected
Based on the results of testing the raw material demand data above, obtained the significance value for the five raw materials is greater than 0.05 (> 0.05). Namely: 0.200; 0.165; 0.200; 0.200 and 0.117. Then H₀ is accepted, which means that raw material demand data is normally distributed.

4.5 Analysis of ADI (Average Demand Interval)
Where, for the ADI value < 1.32 then the inventory system can use a continuous review system. While if the value of ADI > 1.32 then the inventory system is recommended to use a periodic review system. Based on the calculation, the ADI value for each material is 0.91 and 1 where smaller than ( < 1.32 ). So, the supply system can use a continuous review system. [10]

4.6 Calculation of Existing Inventory
Calculation of existing inventory is only a simple multiplication carried out in 2018 – 2019. The result of this calculation is presented in table form as in table 3

| Raw Material | Total Cost of Inventory Existing |
|--------------|---------------------------------|
|              | Total Cost of Inventory (OT)    |
|              | 2018 (Rp) 2019 (Rp) Amount (Rp) Average (Rp) |
| Dinir        | 63.245.000 67.683.170 130.928.170 65.464.085 |
| Satin        | 77.008.640 84.252.536 161.261.176 80.630.588 |
| Folyfoam     | 47.725.100 49.831.820 97.556.920 48.778.460 |
| Bisban       | 38.207.350 40.787.813 78.995.163 39.497.582 |
| Kanvas       | 70.457.040 78.079.952 148.536.992 74.268.496 |
| Total        | Rp 308.639.211 |

4.7 Inventory Planning with Q Back – Order Model

| Raw Material | qo (meters) | r (meters) | S (meters) | ss (meters) | η (%) |
|--------------|-------------|------------|------------|-------------|-------|
| Dinir        | 545         | 58         | 603        | 37          | 99.41%|
| Satin        | 778         | 111        | 889        | 78          | 99.42%|
| Folyfoam     | 458         | 33         | 491        | 17          | 99.60%|
| Bisban       | 1748        | 170        | 1918       | 115         | 99.92%|
| Kanvas       | 283         | 38         | 321        | 27          | 98.12%|
| Total Value Service Level (η) | 99.30% |
### Table 5. Total Proposed Inventory Cost

| Raw Material | Total Inventory Cost (OT) |
|--------------|--------------------------|
| Dinir        | Rp 60,340,531             |
| Satin        | Rp 74,321,366             |
| Folyfoam     | Rp 45,034,366             |
| Bisban       | Rp 36,532,836             |
| Kanvas       | Rp 68,497,955             |

Analysis of Raw Material Inventory Planning Considering Demand Uncertainty [13] &[14] Inventory charts the five types of raw materials can be seen in for example Figure 1, from the graph, it is known the value of $q_0$, $r$, $S$, and $s_s$ with leads time 2 days. Dinir Raw Material Inventory Chart.

![Figure 1. Graph of Continuous Review System (Q) Dinir Raw Material](image)

Furthermore, the service level for each type of raw material is calculated Q back order model can be seen in table 6 below.

### Table 6. Service Level

| No | Raw Material | Service Level $\eta$ (%) |
|----|--------------|--------------------------|
| 1  | Dinir        | 99.41 %                  |
| 2  | Satin        | 99.42 %                  |
| 3  | Folyfoam     | 99.60 %                  |
| 4  | Bisban       | 99.92 %                  |
| 5  | Kanvas       | 98.12 %                  |
|    | Rata – Rata  | 99.30 %                  |

From table 6 the average service level is 99.30%, this is a good service level value because of the method probabilistic inventory always has the possibility of a deviation, in the form of lack of supplies so it is difficult to guarantee the level of availability of materials standard reaches 100%.

After doing the calculation, get the difference in total inventory costs existing and proposal. For dinir raw materials obtained savings of 7.83%, satin 7.82%, folyfoam 7.68%, bisban 7.51% and canvas at 7.77%. From the calculation results obtained total total existing costs amounting to Rp 308,639,211 while, the expected total cost of proposed inventory Q back-order model of Rp. 284,727,054. Where is the probabilistic method of the model Q back – order Hadley – Within algorithm, provides savings of Rp 23,912,157 or equal to 7.75% of the total cost of the existing inventory of the company.

5. Conclusion

Based on data processing and analysis of the results of research that has been done, it can be concluded that: supply chain networks, it is necessary to improve overall operational efficiency and customer satisfaction through coordination and collaboration between all network members namely,
service providers, partners, suppliers, collaborators, and advisor [17] & [18]. After processing the data and analyzing the results of the research it can concluded that the five types of raw materials are continuous material based on ADI classification. So the model is used Continuous Review System (Q) back order of Hadley – Within algorithm. Based on the results of calculations using the model, obtained parameters for optimal inventory planning on raw material inventory at PT. X as follows. of the five types of raw materials obtained the overall average level service that is reaching 99,30% which is considered good. Based on probabilistic inventory calculation Continuous Review System (Q) model back order that has been done, the total inventory cost is obtained optimal (OT) of Rp. 284.727.054. From the acquisition obtained the difference in the total cost of the proposed inventory with the actual amount of Rp. 23.912.157, resulting in a savings of 7,75%.

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