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Planning of Raw Material for Wooden Pallet using Probabilistic Inventory Model

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ABSTRACT

Wooden pallet industry often experienced either shortage or exceed of raw materials which makes the industry suffer for a significant losses due to the company's inability to provide products to fulfill the demand. This deficiency is due to the fact that the company did not have a proper inventory planning of raw material required for the production, as a consequence the company often has to buy the raw material at a higher price in an urgent condition. In order to make a cost efficiency, the activities of purchase and usage of this raw materials need to be planned at the best possible cost so that companies can avoid unnecessary waste of operational costs. With the unpredicted of raw material resources used by the company and quantity of consumer demand, inventory policy planning is needed to determine the most economical quantity required and the time for the company to place the order in these probabilistic conditions.

Key Words: Inventory control, Probabilistic Model, Continuous Review Model, Periodic Review Model, Backorder.

1. INTRODUCTION

In achieving the company's goal of making a profit, many factors must be met to fulfill the demands of the products. The company must be able to strive for smooth fulfillment of customer needs of the product at the exact time the product is needed. In ensuring the smooth running of the production process, companies certainly need to maintain a balance of factors that affected to the production process itself, such as the capital required, the methods and equipment used, and also raw materials used for the production process.

Management of raw material inventory has also become one of the important issue related to this smooth production schedule and delivery. By managing the inventory required to fulfill the customer demands, company can achieve the customer satisfaction as well as increasing their financial performance [1]. In order to control the inventory of raw materials for the production process, company have to ensure that the process being done appropriately to avoid excessive investment and storage costs of raw materials, which may occur during the storage period. On the other hand, when shortage of raw material occurs, it will disrupt the production process and furthermore will impact to the loss of sales. The lack of inventory will also brings an impact on the high frequency of ordering raw materials and as well as the raise of total cost of supplies.

At a medium-sized level of wooden pallets manufacturer in Bekasi area, Mahogany and Rubber Timber are the main raw materials used to produce the wooden pallets required for The Companies as a tool for transporting their products, so that the transportation product can do large quantities by using forklift.

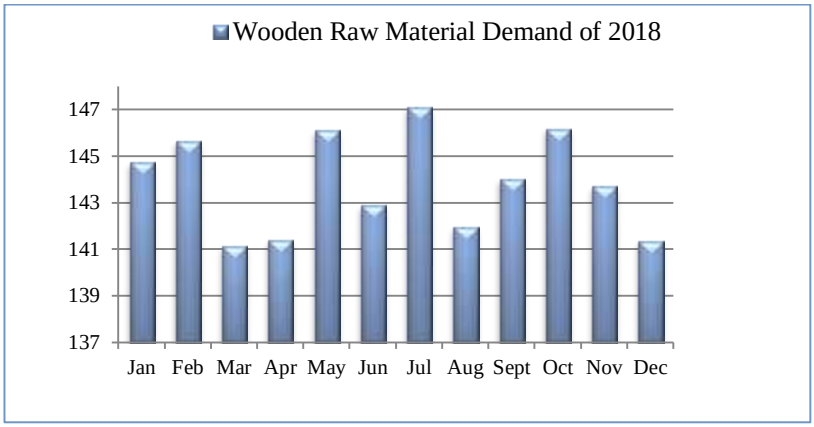

Figure 1. Demand for Wooden Pallet Raw Material

As can be seen in Figure 1, The need for raw materials for wooden pallets in 2018 are quite high and volatile. Each day, the company must be able to provide 300 pcs of wooden pallets, so the company needs to plan the purchase and supply of wood pallet raw materials to anticipate demand but also be able to control costs for the inventory. For current condition, Company has not applied any fixed and well-planned order pattern, so that the order is made after checking and found that their inventory level is low and required stock replenishment. With continuous monitoring of raw material supplies, the company will be able to calculate the risk of unavailability of raw materials from providers, or high raw material prices due to the lack of raw materials in the market.

The probabilistic inventory model is applied for conditions where either demand or the lead time or both is not certain [2]. The probabilistic method is divided into two models, namely the Periodic Review (P-Model) where the order period always fixed and the Continuous Review (Q-Model) where the number of orders is always fixed for each order. As for the two P and Q models, these two policies are imposed two conditions; if at the time of a shortage the customers are willing to wait namely Backorder or Lost sales if the customer does not want to wait [3].

The current condition of the customer practice was that they are willing to wait for the company to reorder and manufacture the Wooden pallet, this happened due to they already committed to the sales contract. this condition may profitable to the company as they will not lose any opportunity to the sales profit, but in other hand they will may impact to the customer satisfaction. To have a proper inventory planning, the company needs to observe which models of the two policies need to be implemented in order to have a lower the total costs of inventory so that company can get better profits.

2. LITERATURE REVIEW

2.1 Probabilistic Inventory Model

Inventory is an asset which includes goods belong to the company with the intention of being sold in a normal business period or inventory of goods that still in a progress of production process, or inventory of raw materials awaiting their use in a production process (Assauri, 2004).

Syukron and Kholil (2014) state that inventory is an idle resource waiting for further processing. According to Bahagia (2006), in a daily life, the phenomenon of the probabilistic inventory is often encountered, stated in a supply that contains of uncertainty. The uncertainty referred here is not random but with a known probability distribution pattern. Statistically, probabilistic phenomena are phenomena which population parameters can be predicted, either the expectation, variance, or likelihood distribution pattern. The probabilistic inventory system is used when one of the demand, lead time or both cannot be known with certainty. On this probabilistic phenomenon, the main concern is to analyze the pattern of inventory behavior during the lead time.

There are two basic models for this probabilistic condition, namely the Periodic Review Model (P Model) and the Continuous Review Model (Q Model). Operationally this inventory policy is translated into three decisions:

1. The size of the economic order lot (q_o)
2. The re-ordering period (r)
3. Determine the amount of safety reserve (ss)

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2.1.1 Cost of Inventory

The performance criteria which are the objective functions of this probabilistic inventory model are to minimize the total cost of inventory (O_T) during the planning horizon by optimizing the service level, which according to Bahagia (2006) stated as follows:

$$O_T = O_b + O_p + O_s + O_k$$

1. Purchase Cost (O_b)
   Purchase cost (O_b) is the price per unit *of* purchased *item*, or production cost per unit if produced within the company. The cost of purchasing goods is the multiplication of the estimated number of goods purchased (D) and the price of goods per unit (p), which written as follows: $O_b = D \times p$

2. Order Cost (O_p)
   The order costs per year can be stated as follows:

   O_p = (cost for each order) × (order frequency per year)
   $O_p = A \times f$
   $f = \frac{D}{Q_0}$
   $O_p = \frac{AD}{Q_0}$

3. Carrying Cost *(O_s)*
   The carrying cost per year is the multiplication of the estimated inventory per year (m) and the storage cost per unit per year (h), written as follows:
   $O_s = h \times m$
   $O_s = h \times \frac{1}{2} Q_0$

4. Shortage Cost (O_k)
   The possibility of a shortage of supplies can occur at any time. Therefore, the safety stock that need to be provided must be able to cope with fluctuations. The amount of the inventory shortage cost during the planning horizon is the multiplication of the expected amount of inventory shortage during the planning horizon (N_T) and the unit cost of the inventory shortage (C_u).
   $O_k = N_T C_u$
   $N_T = \frac{D}{Q_0} N$
   $O_k = \frac{c_u DN}{Q_0}$

3. RESEARCH METHODOLOGY

This research is considering the possibility of stock out arising from the unexpected use of raw materials or because the received time is longer than the expected lead time. To avoid a stock out, safety stock is needed in order to maintain the stock level and fulfill the needs of raw material for production. In the process of obtaining the inventory policy to be applied, this research is following steps as follows:

1. Calculate current inventory policy for the wooden pallets raw material applied by the company
2. Calculate inventory policy using the Model Q with backorder policy.
3. Calculate inventory policy using the Model P with backorder policy
4. Perform comparisons of the three models based on the lowest total inventory cost.

4. RESULT AND DISCUSSION

The need for wooden pallets as raw material is seen from the number of requests for wooden pallets itself, where every piece of finished product wood pallet is made from 22 pcs of Mahogany Wood or Rubber Wood. Table 2 is the demand of Wood Pallet raw materials as reflected from the demand for Wood Pallet products for January 2018 - December 2018

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Table 1. Demand for Wooden Pallet Raw Material

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Quantity	144,716 /Pcs	145,662 /Pcs	141,130 /Pcs	141,394 /Pcs	146,124 /Pcs	142,890 /Pcs	147,114 /Pcs	141,944 /Pcs	144,012 /Pcs	146,190 /Pcs	143,704/Pcs	141,328 /Pcs

To provide raw materials, the company bears a number of costs such as storage costs and ordering costs. Storage costs are costs arising from the purchase of raw materials stored in the warehouse for one storage period, consist of electricity costs and costs for employing supervisors in the warehouse, which are assumed to be 20% of the purchase price of the product, amount as IDR 1.800,- per wood unit. Cost of ordering is the cost incurred for placing a single order, which consists of loading and unloading costs, transportation costs and telephone costs which are calculated at IDR 295.000 per one time order.

4.1 Company Inventory Policy Model

The inventory of wood pallet raw materials carried out by the company at this time did not refer to a specific policy. In 2018, the company recorded that the frequency of orders made in one year was 32 times, where in that one year the company had 1.726.208 pieces of wood pallet raw materials, with a total of 143.851 pcs of one order per month.

1. Purchase Cost
   Purchase Cost = *Item Price x Quantity of Demand*
   = IDR 1.800 *x* 1.726.208 = IDR 3.107.174.400

2. Ordering Cost
   Ordering Cost = *Order cost x Order frequency*
   = IDR 295.000 x 32 = IDR 9.440.000 /year

3. Carrying Cost
   Based on data on purchasing raw materials for wooden pallets, the number of items stored is the average inventory (*m*) of raw materials stored in the warehouse per month or equal to $\frac{1}{2Q_0} = \frac{1}{2}\ x\ 143.851\ = 71.925{,}5 \approx 71.926$ pcs/month
   Carrying Cost = $\frac{1}{2Q_0}\ x\ h$
   = 71.926 x IDR 360
   = IDR 25.893.360 /month = IDR 310.720.320/year

4. Total Cost of Inventory (*TC*)
   TC = Purchase Cost + Ordering Cost + Carrying Cost
   TC = IDR 3.107.174.400 + IDR 9.440.000 + IDR 310.720.320
   = IDR 3.427.334.720/year

4.2 Continuous Review Inventory Model with Backorder (Q Model With Backorder)

Notation

Decision Variabel

*qo** : Minimum lot quantity for each order *(q_o)*
*r** : Reorder point *(r)*
*ss** : Safety Stock *(ss)*
OT : Total Cost of Inventory

Parameter

D = Demand (1.726.208 /pcs)
X' = Average quantity of demand in year 2018
S = Deviation standard = $\sqrt{\frac{(X - X')^2}{N-1}}$
= $\frac{\sqrt{(1.726.208 - 143.851)^2}}{12-1}$ = $\sqrt{143.851}$ = 379,27 pcs

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L = *Lead time* (5 Hari) = $\frac{5}{365}$ = 0,013

S_L = Deviation standard when *Lead time* = S.$\sqrt{L}$ = (43,24 /pcs)

A = Order cost (IDR. 295.000)

P = Item cost per unit (IDR. 1.800/pcs)

h = Storage cost per unit (20% x Rp. 1.800 = IDR. 360 /pcs)

C_u = Shortage cost (IDR.100.000)

Iteration 1

a. Calculate q_{01} using Wilson's formula:

$q_{01} = \frac{\sqrt{2AD}}{h}$

$= \frac{\sqrt{2(295.000 \text{ x } 1.726.208)}}{360}$

q_{01} = 53.188,9 ≈ 53.189 Pcs

b. Calculate α and r_1 using Wilson's formula:

$\alpha = \frac{hq^*_{01}}{C_u D}$

$= \frac{360\ (53.189)}{(100.000)(1.726.208)}$

= 0,00011

From Tabel B for α = 0.00011 → Zα = 3,8.

$Z\alpha = \frac{r1-DL}{SL} = \frac{r1-DL}{S\sqrt{L}}$

$3{,}8 = \frac{r1-(0{,}013\ x\ 1.726.208)}{379{,}27\ \sqrt{0.013}}$

r_1 = 22.605,01 ≈ 22.605 Pcs

c. Calculate q_{02} using Wilson's formula

$q_{02} = \frac{\sqrt{2D[A+Cu\int_{r1}^{\infty}(x-r1)f(x)+dx]}}{h}$

$N = \int_1^{\infty}(x-r1)f(x) = SL[f(Z\alpha) - Z\alpha\Psi(Z\alpha)]$

From Tabel B, $f(Z_\alpha)$ = 0,003 and $\Psi(Z\alpha)$ = 0,00002, thus *N* calculated as follow:

$N = SL[f(Z\alpha) - Z\alpha\Psi(Z\alpha)]$

N = 43,24 [0,003 – 3,8 (0,00002)]= 0,1264 Pcs

$q_{02} = \sqrt{\frac{2(1.726.208)(295.000 + 100.000\ x\ 0{,}1264)}{360}}$

q_{02} = 1.030.582,97≈1.030.583 Pcs.

d. Recalculate α and r_2 using Wilson's formula:

$\alpha = \frac{hq^*_{02}}{C_u D} = \frac{360\ x\ 1.030.582{,}97}{100.000\ x\ 1.726.208}$

$= \frac{371.009.869{,}2}{172.620.800.000}$ α = 0,0021 → Zα = 2,85

$\alpha = \int_{r2}^{\infty} f(x)dx$

r_2 = DL + Zα $S\sqrt{L}$

r_2 = (1.726.208 x 0,013)+ (2,85 x (379,27 $\sqrt{0{,}013}$)

r_2 = 22.563,9 ≈ 22.564 Pcs

e. Compare r_1 and r_2 (22.605 with 22,564), and since there is still variance therefore, the iteration continued with r^* = r_2 = 22,564 and q_0^{2*} = 1,030,583.

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Iteration 2

a. Calculate q_{02} with r_1 = 22.605

$$q_{02}=\frac{\sqrt{2D[A+Cu\int_{r1}^{\infty}(x-r1)f(x)+dx]}}{h}$$

$$N = \int_{r1}^{\infty}(x-r1)f(x) = SL[f(Z\alpha) - Z\alpha\Psi(Z\alpha)]$$

From Tabel B $Z\alpha$ = 2,85, $f(Z_\alpha)$ = 0,0069 and $\Psi(Z_\alpha)$ = 0,0006, then calculate N as follow :

$$N = SL[f(Z\alpha) - Z\alpha\Psi(Z\alpha)]$$

N = 43,24 [0,0069 – 2,35 (0,0006)] = 0,224 Pcs

$$q_{02}=\sqrt{\frac{2(1.726.208)(295.000 +100.000\ x\ 0{,}224)}{360}}$$

$q_{02} = \sqrt{3.043.880.106{,}6}$ = 55.171,37 ≈ 55.171 Pcs

b. Recalculate α and r_2 using Wilson's

$$\alpha = \frac{hq02}{CuD} = \frac{360\ x\ 55.171}{100.000\ x\ 1.726.208}$$

α = 0,00011 → Zα = 3,8

$$\alpha = \int_{r2}^{\infty} f(x)dx$$

$$r_2 = DL + Z\alpha\, S\sqrt{L}$$

r_2 = (1.726.208 x 0,013 + 3,8) (379,27 $\sqrt{0{,}013}$)

r_2 = 22.605,01 ≈ 22.605 Pcs

c. Since r_1 with r_2 already equal as 22.605 therefore we stop the iteration and conclude as follow:

1. The Optimal Inventory Policy:

   q_0^* = (q_{02}) = 55.171 Pcs

   r^* = (r_2) = 22.605 Pcs

   $SS = Z\alpha\ .\ S\sqrt{L}$

   = 3,8 x 379,27 $\sqrt{0{,}013}$ = 164 Pcs.

2. Service Level (η) :

   $$\eta = 1-\frac{N}{DL}\ x\ 100\%$$

   $$\eta = 1-\frac{0{,}224}{1.726.208\ x\ 0{,}013}\ x\ 100\% = 0{,}99 = 99\%$$

3. Ekspected Total Cost of Inventory of Wooden Pallet Raw material :

   $$OT = Dp + \frac{AD}{qo} + h(\frac{1}{2}qo + r - D_L) + C_u\frac{D}{qo}\int_r^{\infty}(x-r)\,f(x)dx$$

   OT = (1.726.208 x 1.800)

   $$+\left[\frac{295.000X\ 1.726.208}{55.171}\right] + 360\left[\frac{55.171}{2}\ 22.605 - 0{,}013\ x\ 1.726.208\right] + \frac{100.000\ x\ 1.726.208}{55.171}\ x\ 0{,}1264$$

   = 3.107.174.400 + 9.299.993,02 + 9.989.996,76 + 395.481,73

   = IDR 3.126.859.871 /year

4.3 Periodic Review Inventory Model With Backorder (P Model With Backorder)

Notation

Decision Variabel

T^* : Order period

*ss** : Safety Stock *(ss)*

OT : Total Cost of Inventory

Using the same parameter with Q Model, therefore we can calculate as follow:

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1) **Calculate T_0 :**

$$T_0 = \sqrt{\frac{2A}{Dh}}$$

$$= \sqrt{\frac{2(295.000)}{(1.726.208)(360)}} = 0{,}03081 \text{ year}$$

2) **Calculate α:**

$$\alpha = \frac{Th}{cu}$$

$$= \frac{0{,}03081 \times 360}{100{,}000} = 0{,}000111 \rightarrow Z\alpha = 3{,}49$$

3) **Count *R* (expected maximum inventory):**

$$R = DT + D_L + Z\alpha\sqrt{T+L}$$

$$= (1.726.208\ x\ 0{,}03081) + \left(1.726.208\ x\ \frac{1}{5}\right) + \left(3{,}49\ \sqrt{0{,}03081 + 0{,}013}\right)$$

$$= 398.431{,}4 \approx 398.432 \text{ unit}$$

4) **Count *N* (the number of shortage):**

$$N = \int_R^{\infty} (z - R) f(z)\, dz$$

$$= S\sqrt{T+L}\,[\,f(Z\alpha) - Z\alpha\,\Psi(Z\alpha)\,]$$

$$= (379{,}27\sqrt{(0{,}03081 + 0{,}013)\,[0{,}0012 - 3{,}49\ (0.00009)]}$$

$$N = 2{,}363 \approx 3 \text{ Pcs}$$

5) **Calculate Total Cost of Inventory**

$$OT = Dp + \frac{A}{T} + h\,(R - DL + \frac{DT}{2}) + \frac{C_u}{T}\int_R^{\infty} (z - R) f(z)\, dz$$

$$OT = [1.726.208 \text{ x } 1.800\,] + \left[\frac{295.000}{0{,}03081}\right] + \left[360\left(398.432 - 75.632x\frac{1}{5} + \left(\frac{1.726.208 \text{ x } 0{,}03081}{2}\right)\right)\right] + \frac{100.000}{0{,}03081}x\,3$$

$$= 3.107.174.400 + 9.574.813 + 147.563.218 + 9.740{,}259$$

$$OT = \text{IDR } 3.274.052.690 \text{ /year}$$

Amend T_0 with 0,05 year, therefore T_0 = 0,08081, then continue to step no. 2 as follow:

2) **Calculate α:**

$$\alpha = \frac{Th}{cu}$$

$$\frac{0{,}08081 \times 360}{100{,}000} = 0{,}000290916 \rightarrow Z\alpha = 3{,}39$$

3) **Calculate *R* (Expected Maximum Inventory):**

$$R = DT + D_L + Z\alpha\sqrt{T+L}$$

$$= (1.726.208\ x\ 0{,}08081) + \left(1.726.208\ x\ \frac{1}{5}\right) + \left(3{,}39\ \sqrt{0{,}08081 + 0{,}013}\right)$$

$$= 484.737{,}50 \approx 484.738 \text{ unit}$$

4) **Calculate *N* (the number of shortage):**

$$N = \int_R^{\infty} (z - R) f(z)\, dz$$

$$= S\sqrt{T+L}\,[\,f(Z\alpha) - Z\alpha\,\Psi(Z\alpha)\,]$$

$$= (379{,}27\sqrt{(0{,}08081 + 0{,}013)\,[0{,}0017 - 3{,}39\ (0.00013)]}$$

$$N = 4{,}12228165 \approx 5 \text{ Pcs}$$

5) **Calculate Total Cost of Inventory:**

$$OT = Dp + \frac{A}{T} + h\,(R - DL + \frac{DT}{2}) + \frac{C_u}{T}\int_R^{\infty} (z - R) f(z)\, dz$$

$$OT = [1.726.208 \text{ x } 1.800\,] + \left[\frac{295.000}{0{,}08081}\right] + \left[360\left(484.738 - 75.632x\frac{1}{5} + \left(\frac{1.726.208 \text{ x } 0{,}08081}{2}\right)\right)\right] + \frac{100.000}{0{,}08081}x\,5$$

$$= 3.107.174.400 + 3.650.538 + 194.169.252 + 6.187.353$$

$$OT = \text{IDR } 3.311.181.544 \text{ /Year}$$

The iteration stops due to the Total Cost is greater than the previous. Thus T_0 = 0,03081.

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Calculate *Safety Stock*:

$ss = Z\alpha \times S\sqrt{L}$

$= 3{,}49 \times 379{,}27\sqrt{0{,}013}$

$= 150{,}9195824$ pcs ≈ 151 Pcs

5. CONCLUSION

As a result, the new proposed of inventory policy can be obtained from both method proposed compared to the current method applied by the company. The summarize of the total cost inventory as shown on Table 2.

Tabel 2. Comparison of Total Cost of Inventory

Model	Total Cost Of Inventory
Company Policy	IDR 3,427,334,720 /year
Probabilistic Model *P (backorder)*	IDR 3.311.181.544 /year
Probabilistik Model *Q (back order)*	IDR 3.126.859.871 /year

As can be seen in Table 2 that the Q model with backorders provides the lowest total cost compared to others. Thus, the inventory policy planning that should be applied by the principle is the probabilistic Q model with backorder. With this Continous Review Model with Backorder, company will need to maintain the level stock with level of ordering lot size is 55,171 pcs, and the reorder point is 22,605 pcs with quantity of the safety stock is 164 pcs.

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