Optimizing Raw Material Orders Using a Comparison of Deterministic and Probabilistic Methods

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Abstract
One of the factors that plays an important role in competition is service to customers. One of the services that can be provided by the company is to provide timeliness in the delivery of goods. An important factor that supports the timeliness is the ordering of the right quantity of raw materials and the time to order the raw materials. Whereas if raw materials cannot be ordered in the right quantity and time, there will be a shortage or excess of raw materials, both of which will cause losses for the company. The research was conducted at a manufacturing company, which is order-based. The problem faced by the company is often experiencing inhibition of the production process and delays in sending orders to its customers. The aim of the research is providing propose regarding the method of ordering raw materials with the right quantity, considering the comparison of storage costs and the cost of ordering raw materials. The result was proposed decision of method to forecasting the need of raw materials, order quantity, and minimizing storage costs and raw material ordering costs.

***Keywords* –**
Manufacturing, material order, order quantity, cost

1. Introduction
In the current era of globalization, the growth of industry is increasingly rapid, thus requiring each industry to give its own advantage to compete competitively in the free market. Both domestic and foreign industries, compete to get customers, because the more customers mean the greater the profit or profit obtained by the company.

One of the factors that plays an important role in competition is service to customers. Good and satisfactory service can increase customer trust and credibility of the company in the eyes of customers. One of the services that can be provided by the company is to provide timeliness in the delivery of goods (Sayid Mia, 2017).

Punctuality should be correctly measured by the company from the beginning of the order recorded, the order produced, until the order is delivered to the customer. An important factor that supports the timeliness is the ordering of the right quantity of raw materials and the time to order the raw materials. If raw materials can be ordered in the right quantity and time, then the production process can run smoothly because raw materials are always available (Naufal et all., 2012). And costs associated with inventory can also be minimized, such as message costs, store fees and backorder costs.

Whereas if raw materials cannot be ordered in the right quantity and time, there will be a shortage or excess of raw materials, both of which will cause losses for the company. Lack of raw materials can be detrimental to the company because it can hamper the production process, increase the cost of messages because they often must order raw materials, lower trust in the eyes of customers, and must pay backorder fees, namely penalty fees for not being able to fulfill customer orders in time. While the excess raw materials in the warehouse can increase storage costs, as well as damage the raw materials themselves due to changes in weather, air humidity, and sunlight so that it can cause raw materials to rust, and the quality of raw materials will decrease and not fit for use.

The research was conducted at a manufacturing company, which is order-based. The problem faced by the company is often experiencing inhibition of the production process and delays in sending orders to its customers. Delays in order delivery are caused by frequent shortages of raw material stock. Calculation of the quantity of raw material ordering done intuitively causes prediction errors because it does not pay attention to the high season or low season. Usually, the company makes an order using the fixed order method, which is every time it makes an order, the quantity of raw materials ordered is the same. As a result, the company must pay a backorder fee, which is a penalty fee that the company must pay to customers for not being able to fulfill the order on time that has been agreed upon by both parties. Sometimes, companies must buy raw material stock from other companies engaged in the same field, but the raw materials are worth 25% more than ordering directly to their suppliers.

Some assumptions as the basis of this research are:

- Forecasting and calculation of raw material requirements are not precise, because they are only based on intuition.
- Inaccuracy in the timing of ordering raw materials back (error prediction for reordering).
- Portals or red lights at ports or airports that make it difficult for goods from abroad to enter.
- Ordered raw materials are not delivered on time.
- Raw materials sent are not in accordance with the order so that they must be returned to the supplier.

From the results of observations regarding the ordering of raw materials applied in the company today, it is known that the ordering of raw materials is not done appropriately. The absence of a definite safety stock determination limit, causing the absence of reserve supplies that can be used in the event of unexpected things. The lack of communication between the warehouse section, and the purchasing part, also causes difficulties in estimating the needs of raw materials in the next few periods.

To overcome the problem of controlling raw materials, it can be formulated some questions as follows:

- What is the right method to be applied in forecasting raw material needs?
- What is the exact quantity of raw materials that must be ordered each period?
- When is the right time to place an order for raw materials by considering various unforeseen possibilities?
- How much safety stock should be prepared to avoid things that are not desirable?

The problem solving can be more focused on research objectives, so that it can provide more meaningful input for the company, the scope of the research will be limited as follows:

- The research location in the division of jeans button products, eyelets, and rivets with brass plate and aluminum plate raw materials that will be the object of research. Because these two types of raw materials are the most widely used raw materials in the production process and the most often run out.
- The research will compare the raw material ordering system used by the company today with the proposed raw material ordering system.
- The research data which will be used is production data for 2017-2020 where the data is used as a reference for forecasting raw material needs in the next period.
- Forecasting raw material requirements is calculated using the help of CB Predictor software, so that the results obtained are more accurate.
- The supplier for each type of raw material is assumed to have chosen the best one among the other suppliers.

- The costs required in the calculation are in accordance with the data provided based on interviews with the production manager.
- The company is assumed to have sufficient capital to purchase raw materials in any quantity.
- The company is assumed to have a large storage area so that it can accommodate any number of raw materials.
- Information systems to be designed are information systems that can help warehouse heads to know the current supply of raw materials, with a FIFO (First In First Out) recording system, which is the raw material that first entered the warehouse will be issued first for the production process.

The aims of this research include:

- Making proper planning regarding the forecasting of raw material needs in accordance with historical production data.
- Providing proposals regarding the method of ordering raw materials with the right quantity, considering the comparison of storage costs and the cost of ordering raw materials. As well as providing proposals when to order raw materials again, in accordance with the forecasting of raw material needs that have been done before.
- Giving a proposal regarding the quantity of safety stock of each type of raw material.

While the benefits that will be obtained from this study include:

- Improving the accuracy of determining the need for raw materials in the future period.
- Improving the accuracy of recording the stock of raw materials in the warehouse.
- Improving the accuracy of determining the order quantity of raw materials.
- Minimizing storage costs and raw material ordering costs.
- Improving the work efficiency of employees in the raw material warehouse and purchasing departments because with the system, they can work faster.
- Assisting the warehouse department to calculate the raw material requirements for each incoming order.
- Increasing customer satisfaction by providing timely delivery of orders.
- Increasing the company's credibility in the eyes of customers.

2. Literature Review

Forecasting was needed in the provision of additional resources, in this case raw materials, where to obtain the raw material, it took a grace period (Smadi, 2012). So that with the forecasting it could help in making decisions about the time of ordering raw materials again and the quantity of ordering of raw materials (Rahman et all., 2013).

From the graph of raw material needs, it turned out that historical data on the use of each raw material form a seasonal pattern with a period of 12 months, so the need for raw materials for the next 12 codes could be predicted (Sundar et all., 2014).

The calculation of manual forecasting by hand was very rare (Rahani and Ashraf, 2012), considering that there were many tools (tools) in the form of software (software) which was widely circulated, which could help perform forecasting calculations with a computer (Domingos et all., 2014). Crystall Ball was one of the software which could be used to perform accurate and easy forecasting- (Raetment,2018). In Crystall Ball, there was a CB Predictor program which has the function of predicting data that will occur in the future by analyzing past data.

In this study, the forecasting model was conducted using the help of the CB Predictor program. This is intended so that the results of the forecast obtained are more accurate. The following will be discussed about forecasting five types of raw materials using the CB Predictor program. The value of "MAPE" is relatively easier to understand in determining the best forecasting results because errors are expressed in percent, while "MAD" is more difficult to understand. For example MAD = 100, is the value of 100 big or small? But with "MAPE", the error is declared in the form of percent compared to the actual (Apreutesei et all., 2010).

Based on this statement, in this study, forecasting with CB Predictor, using "MAPE" as a determinant of the error rate, because it is easier to do further analysis (Spearman et all., 1990).

The following is the result of forecasting calculations using CB Predictor with the smallest percentage of error values (Phumchusri and Panyavai, 2015). While the results of trial and error with autocorrelation analysis, it is analysis using several forecasting methods based on historical data in detail.

3. Methodology

The methodology in this research is descriptive analytic. Research is carried out in the unit in charge of procurement and storage. Figure 1 describes the sequence of activities in this study.

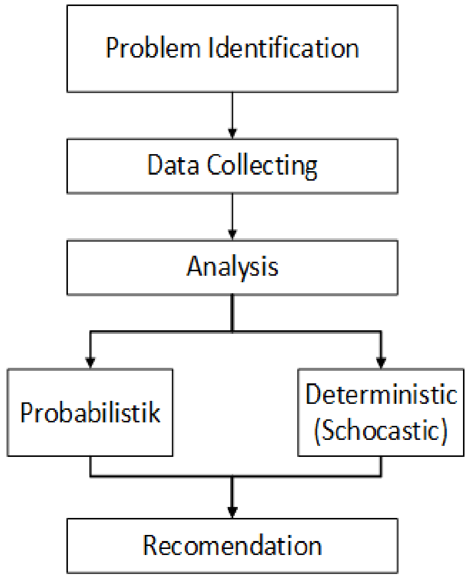

Figure 1. Research Methodology

Data collection is done in the production section because the company does not have historical data on the use of raw materials every month. So the data used in the calculation is production data per month for several types of products that use the same raw materials[8]. Each production process certainly requires raw materials, so production data per month can represent raw material usage data per month.

For details of historical production data over the last three years, namely the period September 2017 to August 2020, which can be seen in the appendix. Similarly, for the products that will be discussed along with the description of components and raw materials of each product in detail can be seen in the appendix.

4. Result And Discusion

Data collection is done in the production section because the company does not have historical data on the use of raw materials every month. So the data used in the calculation is production data per month for several types of products that use the same raw materials (Reatmen, 2018). Each production process certainly requires raw materials, so production data per month can represent raw material usage data per month.

For details of historical production data over the last three years, namely the period September 2017 to August 2020, which can be seen in the appendix. Similarly, for the products that will be discussed along with the description of components and raw materials of each product in detail can be seen in the appendix.

To obtain data on raw material needs per month, the production data must be multiplied by the gross weight of each component with different raw materials. For examples of calculations, it can be seen in the attachment section[9].

The following in table 1 is data on material needs that have been converted from production data during the period September 2017 to August 2020.

Table 1 Raw Material Needs Data (in Kg)

Year	Month	Period	Raw Material Type				
			BP O = 0.23 x 0	BP O = 0.25 x 0	BP O = 0.25 x 0.5	BP O = 0.3 x 0.5	AL O = 1.0 x 0
2017	Sept	1	569.595	622.351	217.777	559.299	198.482
	Oct	2	395.613	800.358	75.024	719.804	241.802

	Nov	3	558.407	622.076	139.237	593.422	169.707
	Des	4	243.175	417.749	62.996	383.612	90.378
2018	Jan	5	451.022	425.389	167.202	429.307	158.976
	Feb	6	663.180	675.781	212.275	654.886	259.290
	Mar	7	3,062.811	1,578.130	1,161.420	2,324.055	734.787
	Apr	8	2,380.747	2,023.235	876.001	2,245.469	769.444
	May	9	2,814.304	1,649.219	1,161.545	2,015.144	727.236
	June	10	2,776.023	1,671.028	814.898	2,015.166	766.105
	July	11	2,127.022	2,096.637	1,100.303	2,129.339	725.964
	August	12	2,532.481	1,675.551	1,233.947	1,822.497	682.246

* BP O = 0.23 x 0 → *Brass Plate* with a thickness of 0.23 cm and hardness = 0
* AL O = 1.0 x 0 → *Alumunium Plate* with a thickness of 1.0 cm and hardness = 0
* A detailed explanation can be seen in the attachment.
From the raw material needs data above, it can be described in the form of a graph as below. The purpose of depictions in the form of graphs is so that the data can be seen more easily and can be known data patterns.

4.1. Raw Material Brass Plate (BP}

- **Raw Materials BP O = 0.23 x 0**

According to Teguh Baroto (2002, p49) the value of "MAPE" is relatively easier to understand in determining the best forecasting results because errors are expressed in percent, while "MAD" is more difficult to understand. For example MAD = 100, is the value of 100 big or small? But with "MAPE", the error is declared in the form of percent compared to the actual.
Based on this statement, in this study, forecasting with CB Predictor, using "MAPE" as a determinant of the error rate, because it is easier to do further analysis.
The following is the result of forecasting calculations using CB Predictor with the smallest percentage of error values. While the results of trial and error with autocorrelation analysis, it is analysis using several forecasting methods based on historical data in detail can be seen in the appendix.
From the results of trial and error with the analysis of autocorrelation results and the use of several forecasting methods, it turns out that forecasting results with seasonality of 12 periods produce forecast data better than the results of predictions with other methods, so that the results of this prediction will be used in subsequent calculations. Seasonality = 12 viewed from the pattern of historical data on the graph showing that historical data patterns form seasonal elements = 12 months.
The following is the result of forecasting raw materials with seasonality = 12 monthly elements.
The details of the results obtained are as follows:

- The best method is: *Holt – Winters' Multiplicative*

$$(\alpha = 0.001 \quad \beta = 0.788 \quad \gamma = 0.001)$$

- *Error* Value: RMSE = 265.06, MAD = 216.64, MAPE = 17.36%
- *Durbin – Watson Value* = 2.582, (in $1.41 < D\text{-}W_C < 1.52$ or $2.48 < D\text{-}W_C < 2.59$) it means that the forecast results are in the unknown area whether there is autocorrelation in the error data pattern or not so that conclusions cannot be drawn from the forecasting results.
- In essence, the Durbin-Watson test is not to test the accuracy of forecasting, but to see if there are still patterns remaining in the error value, but the DW value can help to draw conclusions, where if the DW is in a positive or negative autocorrelation value, the forecasting results are less reliable. trusted.
- *Durbin – Watson Reference test*:

$D\text{-}W_C < 1.41$ then there is a positive autocorrelation.
if, $D\text{-}W_C > 2.59$ then there is a positive autocorrelation.
$1.41 < D\text{-}W_C < 1.52$ or $2.48 < D\text{-}W_C < 2.59$ then the test cannot be concluded.
if, $1.52 < D\text{-}W_C < 2.48$ then there is no autocorrelation.

- *Theil's U Value* = 0.321, it means that the forecasting data is better than the naive estimation, so it can be said that the formal forecasting model is much better.

Forecasting data with seasonality of 12 periods can be seen at table l4.2. As for the comparison of trial and error results with some forecasting methods can be seen in table 4.3.

- **Raw Materials BP O = 0.25 x 0**

From the results of trial and error by entering the element seasonality = 12 (this is seen from the pattern of data showing seasonal elements in 12 periods), it turns out that the results of forecasting with seasonality = 12 produce a forecasting value with the smallest percentage of errors.
When viewed the data plot, the forecasting results with seasonal elements = 12, almost similar to historical data patterns, so the error rate is much lower compared to the results of other forecasting methods.

The details of the results obtained are as follows:

- The best method is: *Seasonal Multiplicative* with α = 0.355 and γ = 0.001.
- *Error Value* : RMSE = 254.38, MAD = 182.79, MAPE = 14.82%
- *Durbin – Watson* Value= 1.585 (in 1.52 < $D\text{-}W_C$ < 2.48 so that there is no autocorrelation in the forecast error).
- *Theil's U* Value= 0.347 (it means that the forecasting data is better than the naive estimation, so it can be said that the forecasting model obtains more accurate results than the naive model.).
- Forecasting data with 12-period seasonality can be seen in the table below.

As for the comparison of the results of trial and error with several forecasting methods can be seen in table 4

4.2 Deterministic Inventory Model

Before calculating the method of ordering economical raw materials, it must first be calculated VC (Variability Coefficient) to determine the most appropriate method. From the vc value, then determined the right method whether continuous method or dynamic method. If the VC < 0.25 then the method used is the continuous method (EOQ), while if VC 0.25 then the method used is a dynamic method, namely the Part Period Balancing method, Wagner & Within, or Silver & Meal.
The formula for performing VC calculations is the same as the formula in the Peterson Silver method.
From the results of VC calculations that have been done for raw materials, the following results are obtained:
Since the VC for all raw materials is greater than 0.25, the methods used in the calculation of ordering economical raw materials are the PPB (Part Balancing Period), Wagner &Within, and Silver &Meal methods. Which then, of the three methods, compares the best results in terms of the lowest cumulative variable cost.

4.3 Part Period Balancing (PPB) Method

- **Raw Materials BP O = 0.23 x 0**

Order fee (A) = Rp 14,188,000 (for carrying capacity of 25.6 tons)
* Details of costs can be seen in the appendix.
Raw material price per Kg (P) = Rp 74,520
Saving Fee (h) = 2% from the price of raw materials
= 2% x Rp 74,520 = Rp 1490.40 / Kg / month
Lead Time (LT) = 60 days (2 months)

PPF (*Part Period Factor*) = $\frac{A}{h} = \frac{14,188,000}{1,490.40} = 9,519.592$

(Note: T always starts with the number 1.)
T is used as the basis of calculation (T-1) * RT.
APP values are derived from accumulated values (T-1) *RT. If the APP is smaller than the PPF, then T continues with the next number. Whereas if the APP is greater than PPF then T is repeated from the number 1.

Calculation example:

* Period 6, T starts from number 1 with RT (demand)= 1,237.474
  (T-1) *RT = (1-1) * 1,237.474 = 0 , APP = 0, APP < PPF, then proceed to period 7 with T= 2
* Period 7, T = 2, (T-1) *RT = (2-1) * 3,302.686 = 3,302.686
  APP = 0 + 3,302.686 = 3,302.686 < PPF, then continue to period 8 and T=3
* Period 8, T = 3, (T-1) *RT = (3-1) * 3,143.217 = 6,286.434

APP = 0 + 3,302.686 + 6,286.434 = 9589.12 > PPF

Since period 8 results in an APP value greater than the PPF, the calculation for period 8 must repeat from T=1. From the table above, the best booking period is obtained according to the method. From the table, then entered the table below for a more detailed calculation of the elements of the cumulative variable cost.

Example of calculation (for orders in the 6th period) :
Period 6, demand = 1,237.474 Kg
Period 7, demand = 3,302.686 Kg
Order quantity = demand 6 + demand 7
= 1,237.474 Kg + 3,302.686 Kg = 4,540.160 Kg
Order per lot = 4,600 Kg (*lot size* in the form of 1 coil = 200 Kg)
Remaining stock (6) = Order per lot – demand (6) + remaining stock (5)
= 4,600 Kg - 1,237.474 Kg + 114.590 Kg = 3,477.116 Kg
Order Fee = Rp 14,188,000.00
Saving fee (6) = remaining stock * saving fee/Kg/month
= 3,477.116 Kg * Rp 1,490.40 = Rp 5,182,293.69
Cumulative Variable Cost = total cost of holding and ordering costs from period 1 to the next period.
Cost of Var. Cumulative (6) = IDR 14,188,000.00 + IDR 4,264,217.72 + IDR 3,150,823.34 + IDR 2,071,445.85 + IDR 1,241,966.71 + IDR 170,784.94 + IDR 14,188,000.00 + IDR 5,182,293.69 = IDR 44,457,532.25

4.4 Wagner & Within Method

- **Raw Materials BP O = 0.23 x 0**

Order fee (A) = IDR 14,188,000
Raw material price per Kg (P) = IDR 74,520
Saving fee (h) = 2% from the price of raw materials
= 2% x IDR 74,520 = IDR 1,490.40 / Kg /month

Wagner & Within method is a trial-and-error method with the sum of the cost of the message and the cost of storage.
Calculation example:
Period 2 has 2 alternative purchases of raw materials, namely purchases made twice (in periods 1 and 2) or purchases made only 1 time (requests for periods 1 and 2 are combined and raw materials are purchased in period 1 only). These considerations are based on a description of the cost of ordering and holding costs, as well as the total cost (TC). For example, in period 2 for alternatives:
Purchase 2 times → Order fee = 2 * IDR 14,188,000.00 = IDR 28,376,000.00
Saving fee = 0 because there are no raw materials stored.
Total cost = IDR 28,376,000.00 + 0 = IDR 28,376,000.00
1 time purchase → Order fee = 1 * IDR 14,188,000.00 = IDR 14,188,000.00
Saving fee = demand period 2 * saving fee
= 747.044 * IDR 1,490.40 = IDR 1,113,095.56
Total Cost = IDR 14,188,000.00 + IDR 1,113,095.56 = IDR 15,301,095.56
When compared based on the total cost, a purchase is twice as expensive as a one-time purchase, so the optimal is a one-time purchase only, with the quantity of orders for raw material needs in period 1 and period 2.
For the third period, optimal purchase data is taken from the second period, and then combined. Since the optimal purchase of the second period = (1, 2), the purchase for the third period has an alternative:
* (1, 2) (3) → purchases 1 and 2 combined (due to optimal results from period 2) and period 3 rebooked
* (1, 2, 3) → purchases are made one-time by combining period requests 1, 2, and 3 and bookings are made in the first period.

Of the two alternatives then compared the lowest cost. And so on, the alternative to the next period proceeds from the optimal alternative from the previous period.
After obtaining the last alternative at the lowest cost, namely bookings made in periods 1, 7, and 10, then included in the following cost calculation table:

4.5 Silver & Meal Method

- **Raw Materials BP O = 0.23 x 0**

Order fee (A) = Rp 14,188,000
Raw material price per Kg (P) = IDR 74,520
Saving fee (h) = 2% x Rp 74,520 = IDR 1490.40 / Kg / month

For period 5, because TRC (5)/5 the value is more increased than the value of TRC (4)/4, it means that the booking becomes inefficient and demand in period 5 should not be ordered at once in the first period because the cost of storage will swell, so in period 5, T must be repeated to T = 1. If T is repeated from the number 1, it means that the period must be rebooked. And that's the next. When the most efficient ordering calculation is found based on the Silver & Meal method, then proceed to perform a more detailed cost calculation as in the table below.

This cost calculation is the same as the cost calculation in the previous calculation. The yellow mark indicates the period during which the booking must be made (regardless of the lead time / grace period of arrival of raw materials after booking).

4.6 Probabilistic Inventory Model

The probabilistic inventory model is calculated using the probabilistic EOQ (Economic Order Quantity) method. The following will be discussed about the steps of calculation using the probabilistic EOQ method for each raw material, namely as follows:

- The raw material needs data above is a single data and must be grouped first so that the probability of use per month can be calculated the expectation of monthly usage and determined the optimal Q.
- Since all data on raw material requirements are 12, the number of classes for each raw material is as follows:

Number of classes → k = 1 + 3.3 log n
k = 1 + 3.3 log 12
k = 4.561 ≈ 5

- As for class width, it is calculated per raw material because each raw material does not have the same amount. The following is a calculation of class width and probability calculation per type of raw material:

- **Raw materials BP O = 0.23 x 0**

- Expected use of raw materials BP O=0.23x0 per month = 2,061.724 kg
- Expected use in a year = 12 x 2,061.724 kg = 24,740.688 kg ≈ 24.8 ton
- The grace period of the message is 2 months, then the expectation of use in the period of the order or HP is 2 x 2,061.724 = 4,123.448 kg ≈ 4.13 ton
- Order fee = IDR 14,188,000 every time an order is made
- Saving fee /Kg / year = 2% from the price of raw materials x 12
= 2% x IDR 74,520 x 12 = IDR 17,884.80
- Calculation of optimal Q:

$$Q \text{ optimal} = \sqrt{\frac{2D(S + BK\sum(K_i - SP)P(K_i))}{h}}$$

Where: D = *Demand* / demand for a year
S = Order fee
h = Saving fee (estimated at 2% of the price of raw material)
$BKP = BK\sum(K_i - SP)P(K_i)$ = Out of Stock Cost

In order to obtain the value of Q optimal, then it must be assumed that $\sum(K_i - SP)P(K_i) = 0$, thus becoming:

$$Q \text{ optimal} = \sqrt{\frac{2DS}{h}} = \sqrt{\frac{2(24{,}800)(14{,}188{,}000)}{17{,}884.80}} = 6{,}272.770 \text{ kg}$$

≈ 6.4 ton (because *lot size* = 0.2 ton)

In the current system, the ordering of raw materials is done with the consideration of fixed quantity and fixed period, namely bookings with the same quantity of each message period and fixed message period, which is four times a year. Receipt of raw materials is scheduled for the period 1 (September), 4 (December), 7 (March), and 10 (June). The period of receipt of raw materials is different from the period of ordering raw materials. This is due to lead time. The ordering lead time for imported raw materials is for two months. So if it is said that the receipt of raw materials in period 1, then the order must have been made two months before period 1 begins.

Consideration of the quantity of orders is taken at the discretion of the company, which wants the order in a stable and fixed quantity. Therefore, companies often experience a shortage of raw material stocks, especially in high season. As a result companies often lose orders or have to buy raw materials from other companies at twice the purchase price directly to the supplier (as a step for emergency procurement).

The following will be discussed about the calculation of cumulative variable costs when applied fixed quantity and fixed period methods in accordance with the company's running system. This calculation is intended as a basis for comparison with the results of the calculation of the proposed method.

- **Raw Materials BP O = 0.23 x 0**

Receipt of raw materials as much as 4x in a year
Quantity for one order 6.0 ton = 6,000 Kg (source : company, 2021)

It turns out that in the 12th period the company will experience a shortage of stock, where if the company will buy raw materials from other similar companies, then the cost that must be incurred to buy raw materials is twice the purchase price of direct materials. But companies can also choose not to buy raw materials from other companies. And as a consequence, the company will lose customers. The large cost of losing a customer is difficult to identify in writing, because it relates to the company's good name or credibility in the eyes of the customer as well as the profits that the company will not get (due to loss of order or loss due to the hampering of the production process).
Suppose the company takes a stand to buy raw materials from other companies, then the cost of inventory shortage charged is as large as: 800 Kg x 2 x IDR 74,520.00 / Kg = IDR 119,232,000.00.

Purchase of raw materials = 800 Kg because *lot size plate raw material* is 200 Kg.
Then, the total cumulative variable cost is IDR 156,302,017.55 + IDR 119,232,000.00 = IDR 275,534,017.55. The total cumulative variable costs show clearly that with the additional costs of inventory shortages, the costs that must be incurred by the company are even greater.

4.7 Safety stock

Siswanto (2007, p191) states that the behavior of demand is always changing up and down, causing the onset of problems of running out of supplies, where as a way out needed reserve supplies or safety stock. Calculation of reserve inventory obtained from the formula:
Reserve inventory = factor of safety x σ
Where: The safety factor is obtained from the percentage of management statements regarding the possibility of the percentage of inventory running out
σ = variance of demand
From the possibility of availability or running out of inventory, then converted through the normal curve table and then obtained the value of the security factor. The conversion value of the security factor can be seen in this table.
The following will be discussed about the calculation of reserve supplies for the five types of raw materials that will be discussed in this study.

- **Raw Materials BP O = 0.23 x 0**
  - Value calculation σ

To get value σ (variance), then this calculation should be done.

  - Calculation of reserve inventory

From the management statement it is said that the percentage of the possibility of depleted inventory for all types of raw materials is 10% and the probability of available inventory is 90%, so from the conversion table above, obtained a safety factor value of 1.28.
Reserve Stock = Safety Factor x σ
Then reserve stock = 1.28 x 1,332.122 = 1,705.116 Kg

4.8 Calculation Result Analysis

According to Siswanto (2007, p187), make-to-order companies do not know the exact demand for products during the period of arrival of raw material orders, so it takes spare supplies to overcome the problem of running out of raw material supplies.

Reserve inventory is not directly related to the calculation of order quantity with either deterministic models or probabilistic models. Because reserve inventory is separate from on-hand stock. Reserve inventory is only in the form of inventory of each raw material with the quantity that has been calculated above, and the reserve inventory will only be used when the stock on -hand has run out, while the product order is still waiting, and the raw materials that have been ordered to the supplier have not reached the raw material warehouse.

Although the determination of raw material needs for the next 12 periods has been done by forecasting methods with the smallest error value, but the forecasting method may deviate from the fact because this method only predicts the demand data of the next few periods of historical data, and in fact there must be something beyond the forecasting. For example, in January, which is usually quiet, but in 2008 suddenly got orders in large quantities. If there is no reserve inventory, then the order will not be able to be fulfilled because it is predicted that in January the demand is not so high.

Therefore, with the reserve inventory, the production process will continue despite unforeseen situations and losses will be minimized customers.

In calculations using deterministic methods and probabilistic methods, the cost for reserve supplies of raw materials is not considered. This is because reserve inventory is a stand-alone supply (not related to the quantity of ordering raw materials), where reserve supplies will always be available in the warehouse of raw materials, and reserve supplies incur fixed storage costs. So that in the calculation of order quantities both using deterministic methods, and probabilistic methods, the fixed cost element of the reserve inventory is not included in the calculation of the total cumulative variable cost.

Table 2 is a cost comparison table of the calculations of deterministic methods and probabilistic methods that have been done above as well as the fixed quantity methods of the systems running in the company today.

Table 2 Comparison of Methods for BP Raw Materials O=0.23x0

Method	Receipts in the period to-	Cumulative Variable Cost (IDR)
PPB	1, 6, 8, 10, 12	98,066,754.01
Wagner & Within	1, 7, 10	92,642,914.01
Silver & Meal	1, 5, 7, 9, 11	95,384,034.01
Probabilistic EOQ	1, 7, 11	101,585,314.01
Running system	1, 4, 7, 10	275,534,017.55

For raw materials BP O = 0.23 x 0, economic ordering is obtained using the Wagner & Within method where calculations using this method are obtained the lowest cost, which is IDR 92,642,914.01 while when compared to the PPB and Silver & Meal methods, the cumulative variable cost does not differ much. These three methods estimate the balance between the cost of saving and the cost of the message, resulting in lower cumulative variable costs when compared to the probabilistic EOQ method.

Calculation of the EOQ method is probabilistic, does not consider cumulative saving costs, where the order is economical using the EOQ method only estimates the cost of saving and the cost of the message only. This causes inventory to accumulate in the warehouse during the low season, and the accumulated inventory raises cumulative storage costs. The EOQ method also does not pay attention to the elements of high season or low season, but considers the needs of raw materials are the same every month, according to the probability of the emergence of the quantity value of needs in one year. So that the quantity of raw materials is less well-regulated according to the comparison of the cost of storage and the cost of the message.

When the proposed method is compared to the current system that is commonly applied by the company, namely by using fixed quantity and fixed period ordering methods, which amount to 6 tons every three months. The cumulative variable cost that a company must incur is much greater than the proposed method. This is because in the current system, the company experiences a shortage of stock in the high season, so the company must buy raw materials from other companies, as emergency raw material procurement, at twice the price of buying from direct suppliers.

In addition, the system method does not pay attention to the high season and low season, so the quantity of orders that are less careful can result in a shortage of supplies, while in the low season, raw materials accumulate in the warehouse of raw materials.

Using the Wagner &Within method, acceptance is made three times a year, namely periods 1, 7, and 10, and the quantity is adjusted to the high season or quiet, so that variable costs can be minimized as low as possible. The acceptance period is different from the booking period, this is due to lead time. Lead time is the grace period between ordering and receiving raw materials. For imported raw materials, the lead time needed is for two months, so for raw materials to be received in the first period, the raw materials must be ordered two months before the first period begins.

For raw materials BP O = 0.25 x 0, calculations with the PPB method produce the lowest cumulative variable cost compared to other methods, which is IDR 71,292,676.52.

The PPB method considers the comparison of cumulative savings costs and message costs, so that costs associated with inventory can be minimized. In addition, the quantity of ordering is also adjusted to the needs of raw materials, so that supplies can be arranged in such a way, so that in the high season raw materials are not lacking and in the low season, raw materials do not accumulate in the warehouse.

Unlike the probabilistic EOQ method and the system method, where the high season and low season are not cared for, so it can cause cumulative storage cost overruns or the cost of inventory shortages.

Calculations with the probabilistic EOQ method, resulting in the same admission period as the PPB method. However, the cumulative variable cost of the EOQ method is greater than that of the PPB method. This is because the EOQ method determines the optimal Q* quantity that is not adjusted to the high season or quiet, so the cumulative saving cost is greater than the PPB method.

For raw materials BP O = 0.25 x 0.5, the best method is obtained by the Silver & Meal method, which with the method incurs the lowest cost of other methods. With this method, bookings are made three times, namely in periods 1, 7, and 10, with a cumulative variable cost of IDR 61,155,355.86.

For the probabilistic EOQ method, the cumulative variable cost is greater than the deterministic method. Optimal Q* calculation is based on calculating the probability of raw material needs for one year, so it does not consider the existence of a busy or quiet season, but instead pays attention to the frequency of emergence of raw material needs numbers. Thus, the cumulative saving cost soars compared to deterministic methods.

While the method on the system runs, resulting in raw materials running out during crowded periods, so it must be incurred additional costs for the procurement of emergency raw materials that are twice as expensive as the purchase price of raw materials from direct suppliers.

For raw materials BP O = 0.3 x 0.5, the method chosen is the PPB method, where this method produces the lowest cost than other methods. Raw material orders are made in periods 1, 7, and 10, with a cumulative variable cost of IDR 73,063,838.30.

When compared to the EOQ method the cumulative variable cost is greater than the PPB method. Likewise with a running system that results in cumulative variable costs that soar.

Both the EOQ method and the method applied to the running system, do not pay attention to the high or quiet season, so often raw materials run out during high season and accumulate during the low season. Even though raw materials both run out or that accumulate in warehouses both cause costs, namely the cost of inventory shortage and cumulative storage costs. The cost of inventory shortages can be in the form of emergency raw material procurement costs, penalty fees or fines from customers due to delays in delivery of products, or loss costs due to hampered production processes.

When viewed the above methods, it turns out that all methods refer to the acceptance of raw materials with the same period, namely periods 1, 7, and 10. With the order in the same period for all types of Brass Plate raw materials, the company can make savings once again, where phone costs and administrative costs will be used as a one-time order for all Brass Plate raw materials. And coupled with the cost savings of loading and unloading with forklifts, because if the order quantity is above 25.6 tons, then the additional cost for forklifts is calculated per hour, and the cost is cheaper than having to call forklift services every time you must unload.

Therefore, with this proposed method, the company can make cost savings in ordering raw materials, when compared to the current running method, where the method incurs far greater costs than the proposed method. In addition, with the forecasting of raw material needs, it can help the company's management to know the estimated needs of raw materials in the future and can calculate the quantity of raw materials more carefully, as a basis for anticipating orders from customers. So that customer satisfaction can be maintained, and the company can also save costs related to the supply of raw materials.

For aluminum raw materials, the most economical order is to use deterministic methods. Both PPB, W &W, and S &M methods, result in the same cost, which is IDR 1,774,519.05. The acceptance period with the three methods is the same, namely the 1st, 2nd, 3rd, 5th, 6th, 7th, 8th, 9th, 10th, 11th, and 12th periods. Since the lead time for aluminum raw materials is one month, the booking is made for one month before the acceptance period begins.

Bookings are made almost every month because of the cheap message fee, which is IDR 57,734. While the cost of saving IDR 1,050 per Kg of raw materials. Considering the balance between the cost of the message and the cost of saving resulted in the booking being made almost every period.

While the calculation of the EOQ method, produces an optimal Q* value of 200 Kg, while there are several periods in high season requiring more raw materials than the optimal Q*. So that in the crowded period the quantity of order is adjusted to the needs of raw materials. However, the cumulative variable cost is greater than the deterministic method, so the deterministic dynamic method is a more suitable method to apply.

When compared to a running system, it is clearly seen that the running system incurs the most costs among the proposed methods. The quantity of orders that are not considered can inflate the costs associated with inventory.

Overall, the best method to apply in a company is the deterministic dynamic method. Based on the results of calculations by comparing several methods, dynamic deterministic methods always provide a solution to save inventory costs. Thus, this method can be used to assist companies in determining the most economical quantity of ordering raw materials, because it is accompanied by a comparison of message costs and cumulative saving costs.

5. Conclusion

As a make-to-order company engaged in button making. The problem faced by companies today is the supply of raw materials that often run out, due to the determination of the quantity of ordering raw materials that are not appropriate because it is done based on intuition and the absence of reserve raw material supplies. This certainly causes losses for the company, especially in terms of costs due to the production process that is hampered or must procure emergency raw materials to fulfil customer orders.

Therefore, several stages are proposed that must be taken in determining the quantity of ordering raw materials. The first step is to collect historical data on the use of raw materials, then make an forecast of raw material needs for future periods. The next step is to calculate the quantity of order based on forecasting data, by comparing deterministic methods and probabilistic methods. In addition, there is also a calculation of safety stock or reserve supplies for each raw material so that it can overcome situations outside normal conditions, such as order surges.

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