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Inventory planning of raw material using Silver Meal and Wagner Whitin Algorithm

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Abstract: Material inventory planning is needed in the industrial world to advance a business because it will affect the costs incurred, the production process, and the profits generated by the company. The company has a problem that occurs when the control of raw material inventory could be more optimal. It recorded that throughout 2021, 33.647,18 meters of fabric pants were stored in warehouses. This is influenced by several factors, including the calculation of safety stock, lead time due to uncertain logistics and the selection of methods that have not been maximized. The novelty of this research is that it discusses inventory planning, the methods used are Silver Meal Algorithm and the Wagner Whitin Algorithm. Data processed is on demand for clothes and jeans throughout 2021. The results show that the Silver Meal is suitable for five materials, and the Wagner Whitin Algorithm is on one material. Companies can use both methods for each raw material. Nevertheless, it is more optimal if the company utilizes only one method for procurement of raw materials, the Silver Meal because when it is used in the long term, the cost of raw materials is less than the Wagner Whitin Algorithm. The Siler Meal's total inventory cost is Rp. 138.281.497, and the Wagner Whitin Algorithm is Rp. 170.010.097.

1 Introduction

The business world continues to experience developments in meeting the various needs of consumers who continue to grow and are competent in choosing what they need. Consumers in the middle to upper class always look for good quality at a more affordable price. To meet consumers' needs and desires, companies must have an optimal supply of raw materials. Therefore, a company must have suitable raw materials in an inventory control system [1]. Inventory is part of a company that plays a vital role in a business operation, so a company is asked to carry out the management that can help the company's conditions that occur in inventory management to achieve the desired goals. Inventory management is of utmost importance part of a company that produces a product, with inventory management, stock balance can be achieved without excess stock and shortage of stock [2]. A company needs effective inventory management so that the company can conduct a seamless production process to enable the sustainability of company processes [3]. The intended purpose is to minimize the company's costs to control its inventory. Material inventory planning is needed in an industry to develop its business because it will affect the costs incurred, the production process, and the profit generated by the company [4].

This company is an industrial company in the garment sector and has exported to various countries. Cloth pants and jeans are products that are always ordered by consumers, even though the demand is dynamic. From the results of the interviews, it is known that one of the problems faced by the company is controlling the availability of raw materials that could be more optimal. The high inventory in the warehouse causes an increase in storage costs in the warehouse and the company's profits are not optimal. Throughout 2021, it was recorded that 33.647,18 meters of fabric pants were stored in warehouses, and this led to an increase in the cost of procuring these raw materials. Fabric is the primary raw material for the production of trousers and jeans. Demand for the company constantly changes every month. The demand function depends on the marketing and operational activities of the company. Several factors that affect the

demand function include price, rebate, lead time, space, quality, and advertising [5]. In other words, the quantity of demand is dynamic, but the company uses a static inventory method. This is the cause of overstock.

Forecasting is very important and widely used at every stage of the supply chain from supplier to customer. Including the problems in meeting consumer demand. The dynamic quantity of demand for raw materials makes companies need to apply forecasting methods. Good forecasting helps companies take the right policies such as determining how many items to produce and how to set target inventory levels to minimize stockouts so inventory storage costs can be reduced [6].

Dwiputranti and Gandara conduct research with the aim of reducing consumer demand stockout fluctuations and minimizing costs incurred during one period. Based on the results of the study, it was found that the silver flour method can minimize the total cost of procurement by saving Rp. 26,773,013 or 4.15% [7].

Usman, in his research with the intention of avoiding excess or shortages of raw materials, such as in those periods previously. The result of this research is the Wagner Algorithm method Within is the best proposed method because of the high cost of inventory the most efficient use of Rp. 11,533,000 [8].

Azwir explained in his research that the consignment stock and mix strategy 4P methods are most suitable for solving inventory problems. This study obtained a decrease in inventory value by 26%, and the amount of stock decreased from 149 days to 98 days [9].

Fadhil, in his research, implemented the Min-Max stock method to solve inventory problems and the Waterfall method as an inventory information system. This research succeeded in cutting inventory costs in the company and managing inventory records in a unified and centralized way [10].

In this study, the company still uses the static inventory method, which causes overstock, so two methods are applied. The best method is chosen based on the least cost inventory.

1.1 Inventory

The term "inventory" refers to the materials, parts, and materials-in-progress that a corporation has on hand for a production process as well as the final components or products that are accessible to satisfy orders from component customers at any moment. Inventory is an activity that includes the company's goods that are intended to be sold within a certain time frame, as well as inventory of goods that are still being produced and raw materials that are awaiting use in the production process. Inventory has a very important function to support operational continuity company. This function is to provide a choice of goods in order to meet demand customers, to separate several stages of the production process, to take advantage from discounted quantities, and does not avoid inflation [11].

1.2 Forecasting

Forecasting is the art or science of predicting the future. This can be done by projecting historical data into the future with a form-systematic model. Alternatively, it could be by using a combination of mathematical models that are adjusted to the reasonable judgment of a manager [1]. Types of forecasting methods (1), (2), (3), (4), (5), (6), (7):

- Forecasting single moving average **[**12**]**

$$Ft = \frac{A_{t-1}+A_{t-2}+\cdots+A_n}{n} \quad (1)$$

- Forecasting single exponential smoothing

$$Ft = F_{t-1} + (\alpha\,(A_{t-1} - F_{t-1}) \quad (2)$$

- Forecasting the weight-moving average

$$Ft = W_1A_{t-1} + W_2A_{t-2} + \ldots + W_nA_{t-n} \quad (3)$$

- Forecasting error

$$MAD = \frac{\sum|At-Ft|}{n} \quad (4)$$

$$MSE = \frac{\sum(At-Ft)^2}{n} \quad (5)$$

$$MFE = \frac{\sum At-Ft}{n} \quad (6)$$

$$MAPE = \frac{\sum_{i=1}^{n} 100\,|At_i - Ft_i|/At_i}{n} \quad (7)$$

Description:
Ft = forecast,
At = actual demand.

1.3 The methods Silver Meal Algorithm and Wagner Whitin Algorithm

The Silver Meal focuses on the lot size that can minimize total cost per period, where the lot size is obtained by adding up the needs of several consecutive periods as a tentative lot size (8) [13].

$$K(m) = \frac{1}{m}\,(A + hD_2 + 2hD_3 + \cdots + nhD_m) \quad (8)$$

Wagner Whitin Algorithm (AWW) This technique attempts to determine the optimum lot size by evaluating all order quantities to meet the net requirements over the whole planning horizon. The math from AWW is "elegant" to achieve this goal without actually having to consider, specifically, every possible strategy. This is a solution to the lot size for the previously used net requirement schedule (9), (10), (11) [14].

$$Q_{ce} = \sum_{k=c}^{e} D_k \quad (9)$$

$$Z_{ce} = C + h\sum_{i=c}^{e}(Q_{ce} - Q_{ci}) \text{ for } 1 \le c \le e \le N \quad (10)$$

$$fe = \text{Min } \{Zce + fc\text{-}1\} \text{ for } c = 1, 2, \ldots, e \quad (11)$$

Description:
A = order cost,
D = total demand,
h = holding cost.

1.4 Safety stock

Dealing with lot sizing in inventory is increasingly complicated because of requests. Uncertainty in demand can occur because it is influenced by various factors such as weather, the economy, market competition, to the reliability of suppliers. From the time an item is ordered until it is delivered, it might take anywhere from a few hours to several months. The lead time is the amount of time between placing an order and when the products actually arrive. The availability of the items and the distance between the buyer and the supplier have a big impact on the waiting time. Due to the grace period, safety stock, or inventory set aside for needs while awaiting the delivery of the items, is important. To deal with demand uncertainty, safety stock has been employed extensively. A level of item, also known as a stock keeping unit (SKU), known as safety stock is kept in a warehouse to manage unforeseen demand [15].

Safety stock is a unit of inventory that is constantly present in a business to prepare for demand variations and prevent stockouts. Meanwhile, safety stock (safety stock) is an additional inventory stored to protect against variations in sales levels or more recently in manufacturing or delivery [16,17].

2 Methodology

This study includes quantitative research using historical data on demand for cloth pants and jeans from January 2021 to June 2022. Other data were obtained from interviews with this company.

After all the data is collected, the data is processed by following these steps:

- Forecasting single moving average (equation 1),
- Forecasting single exponential smoothing (equation 2),
- Forecasting the weight moving average (equation 3),
- Calculation of forecasting error (equation 4, 5, 6, 7),
- Calculate inventory costs which include ordering costs (A) and holding costs (h),
- Calculating inventory planning costs using the Silver Meal (equation 8),
- Calculating inventory planning costs using the Wagner Within Algorithm (equations 9, 10, 11),
- Calculating safety stock,

$$SS = Z \times \sigma \times \sqrt{L} \quad (12)$$

Description:
SS = safety stock,
Z = service level,
σ = standard deviation,
L = lead time.

- Comparing calculation costs with the company

Holding costs consist of maintenance costs, warehouse electricity costs, and warehouse keeper salaries, which are calculated based on the capacity of the warehouse and each raw material.

Table 1 Holding cost

Materials	Cost/Unit/Month (Rp)
Fabric	657
Yarn	1.460
Zipper	1.460

The cost of messages for the procurement of raw materials is the total telephone, administrative, and shipping costs for each raw material. The procurement of raw materials for fabric is Rp. 6.800.000, yarn and zipper is Rp. 1.500.000. The following are the details of the booking fees made by PT. XYZ

Table 2 Ordering cost

Ordering Cost	Cost
Administration Fee	Rp. 150.000
Telephone	Rp. 150.000
Shipping cost Fabric	Rp. 6.500.000
Shipping cost Yarn	Rp. 1.200.000
Shipping cost Zipper	Rp. 1.200.000

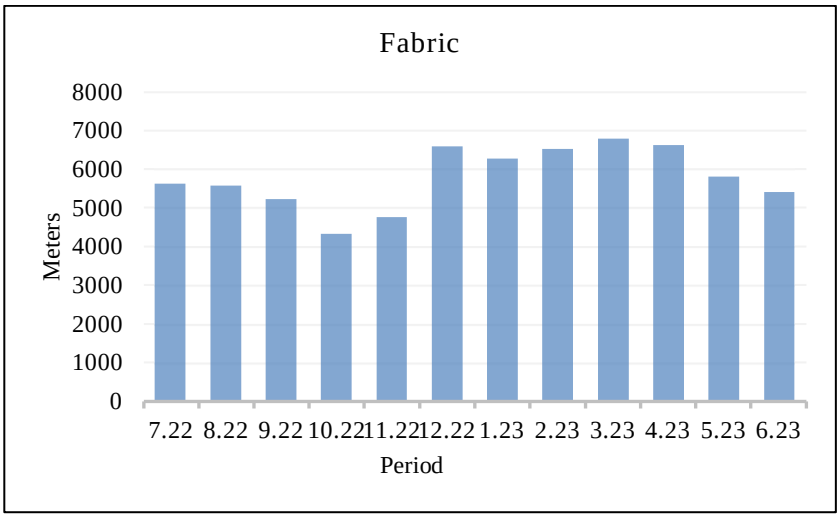
3 Result and discussion

3.1 Forecasting

From the forecast error rate calculation, the method chosen for the demand for cloth pants and jeans is the weight moving average because it has a minor error value. The following forecast results from cloth pants and jeans.

Table 3 Raw Material need for cloth pants

Period	Fabric (Meters)	Yarn (Rolls)	Zipper (Pieces)
July 2022	5615.4	428	4000
August 2022	5572.9	424	4000
September 2022	5222.8	396	3700
October 2022	4334.2	328	3100
November 2022	4750.9	360	3400
December 2022	6579.2	500	4700
January 2023	6270.2	476	4500
February 2023	6509.7	492	4600
March 2023	6786.1	516	4800
April 2023	6613.2	500	4700
May 2023	5795.4	440	4100
June 2023	5397.2	408	3900
Total	**69447.2**	**5268**	**49500**



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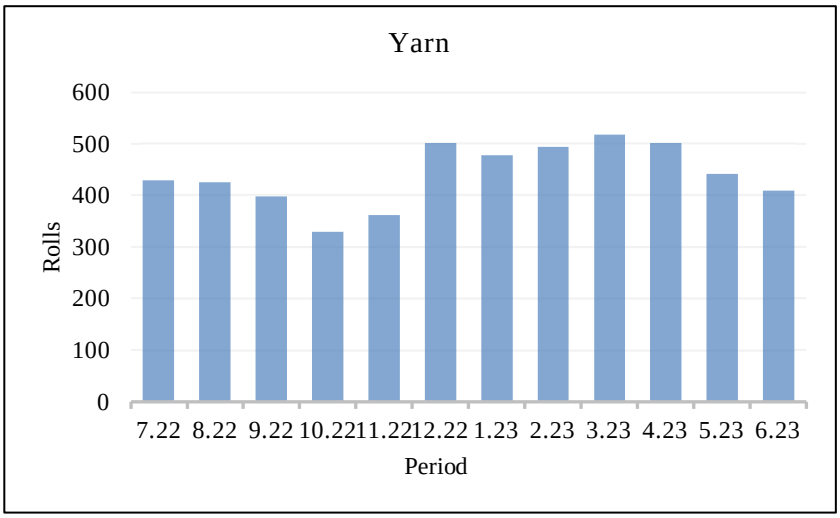

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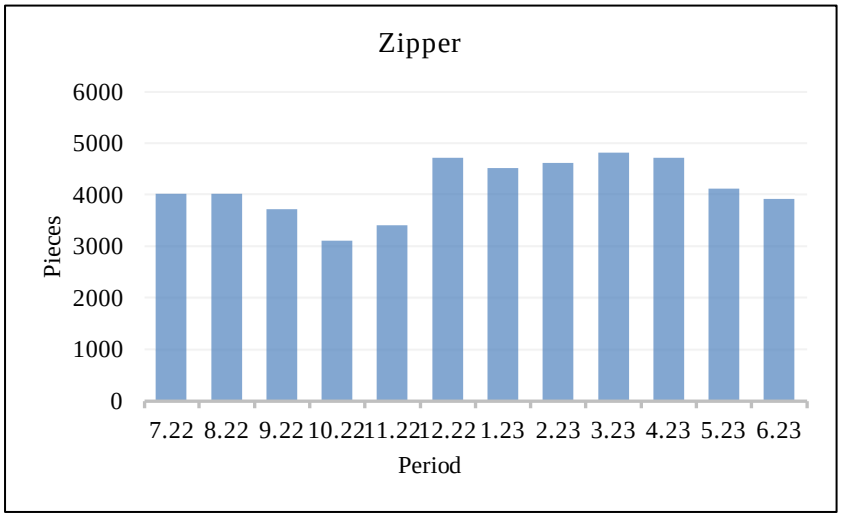

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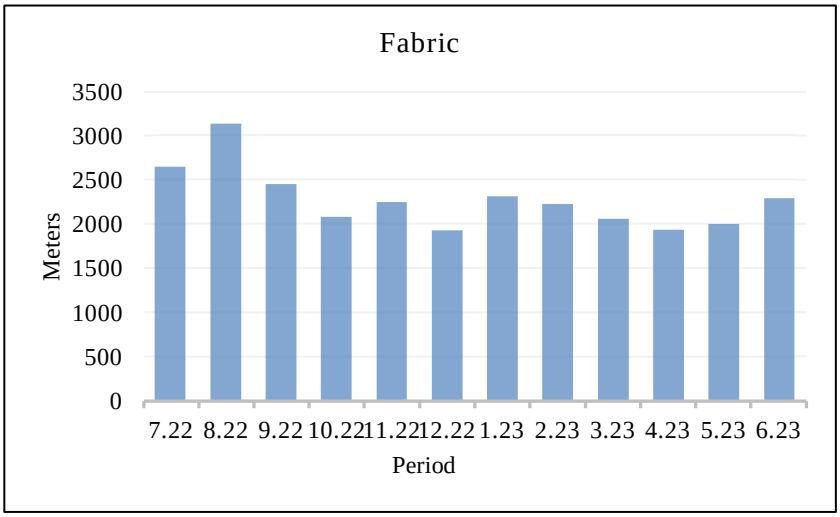
Figure 1 Materials needs for cloth pants

Table 4 Raw Material needs for jeans

Period	Fabric (Meters)	Yarn (Rolls)	Zipper (Pieces)
July 2022	2641.693	208	1900
August 2022	3122.001	244	2300
September 2022	2439.681	192	1800
October 2022	2072.387	164	1500
November 2022	2237.669	176	1600
December 2022	1918.406	152	1400
January 2023	2305.477	180	1700
February 2023	2215.067	176	1600
March 2023	2055.435	164	1500
April 2023	1925.469	152	1400
May 2023	1997.515	156	1500
June 2023	2284.287	180	1700
Total	**27215.088**	**2144**	**19900**



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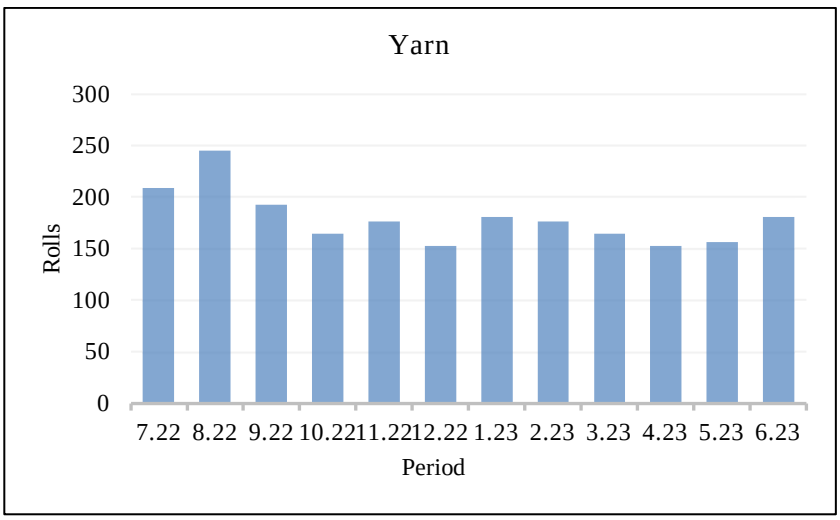

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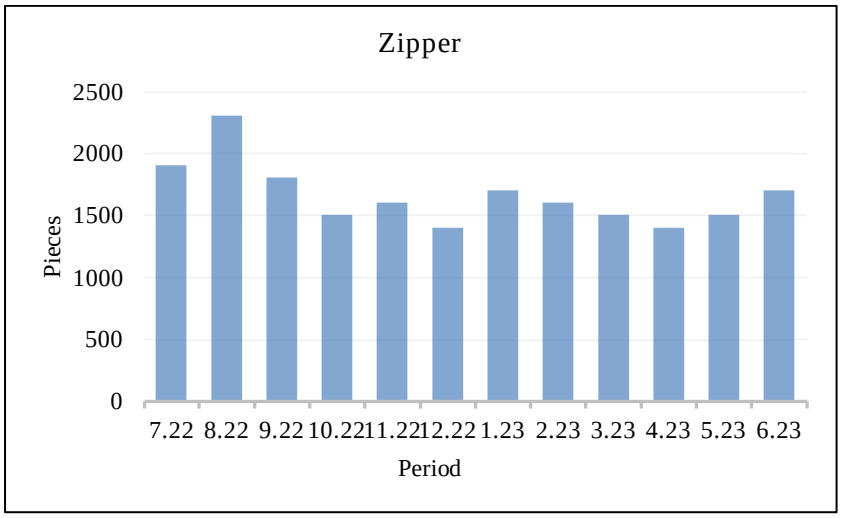

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Figure 2 Materials needs for jeans

3.2 Safety stock

An additional inventory known as "safety stock" is kept on hand to guard against or sustain the risk of material shortages (stock out). Using the findings of the calculations, the six different categories of raw materials were given safety stock. The quantity of safety stock will vary depending on a number of factors, including the volume of orders, the degree of service, and the lead time. Based on the calculation results, different safety stocks were obtained for the six types of raw materials, namely 283.86 meters for fabric trousers. The company must have a minimum inventory of 283.86 meters of fabric pants to anticipate raw material shortages in the production process. Similarly, twenty rolls of yarn for fabric pants with safety stock, 200 pieces of zippers for fabric pants, 124.56 meters of jeans fabric, eight rolls of yarn for jeans, and 100 pieces of jeans zippers. The size of the safety stock will depend on several things, such as order frequency, service level used, and lead time.

Table 5 Safety stock

Materials	Safety Stock
Fabric Pants	283.86 meters
Yarn Fabric	twenty rolls
Zipper Fabric	200 pieces
Fabric Jeans	124.56 meters
Yarn Jeans	eight rolls
Zipper Jeans	100 pieces

3.3 Inventory planning

Inventory planning calculation uses two methods: Silver Meal and Wagner Whitin Algorithm. These two methods determine which produces the lowest inventory cost, and the Silver Meal determines the average cost per period.

Additional orders are made when the average cost of the second period is still less than the average cost of the first period. Suppose the cost of ordering the second period is higher than that of ordering the first period. In that case, the calculation is carried out as before, starting again with the previous period. Meanwhile, the Wagner Whitin Algorithm aims to find the most optimal alternative among all existing alternatives. This method's stages include calculating all alternative orders based on the period. If we have obtained the results of alternative calculations, the next step is to find the lowest cost for each period. Then the lowest cost from each period becomes a reference to determine how many times to order from each item.

In comparison to the total inventory cost supplied by the company, calculations using the suggested approaches Wagner Whitin Algorithm and Silver Meal Algorithm produced a minimum total inventory cost. The ideal order quantity utilizing the two recommended techniques, which is smaller than the total cost of inventory, shows the difference in the overall cost of the company's inventory with the proposed method. The results differ from the company's total inventory expenses since the optimal order quantity will lower the ordering cost, which is rather high. The table below shows the prices for the two and the company's procedures.

Table 6 Comparison of total inventory cost

Materials	Total Inventory Cost		
	Silver Meal (Rp)	AWW (Rp)	Company's (Rp)
Fabric Pants	66.838.881,1	72.329.250,1	99.447.535
Yarn Fabric	7.418.540	11.313.220	16.359.260
Zipper Fabric	7.794.340	11.357.020	15.402.960
Fabric Jeans	47.029.416,3	66.421.726,9	56.338.048,6
Yarn Jeans	4.956.400	5.571.940	7.113.980
Zipper Jeans	4.243.920	3.016.940	7.974.500
Total	**138.281.497,4**	**170.010.097**	**202.636.284,6**

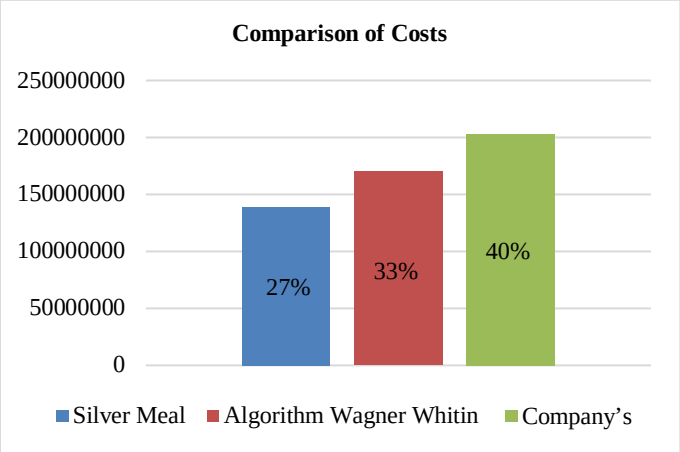

Figure 3 Comparison of costs

Table 6 and figure 3 show differences in total costs using the three methods. The company's calculation results are more expensive than the two tested methods, namely the Silver Meal Algorithm and the Wagner Whitin Algorithm.

The computation yields Silver Meal have a nominal total inventory cost than the Wagner Whitin Algorithm method, and this is influenced by ordering costs and storage costs. Although storage costs using the Wagner Whitin Algorithm are, on average, smaller than the Silver Meal, the ordering costs using the Wagner Whitin Algorithm are more significant than the Silver Meal method.

Based on the results of the calculations, the most recommended and suitable method is to be applied at PT using the two proposed methods. XYZ is a Meal for the raw material for making cloth pants, fabric jeans thread Silver. As for the zipper of jeans method, using the Wagner Whitin Algorithm is more optimal. However, it is more optimal if the company utilizes only one method for the procurement of raw materials, namely the Silver Meal Method because when used in the long term, the costs incurred for the procurement of raw materials are lower than the Wagner Whitin Algorithm method.

4 Conclusions

The conclusion of this study is the result of data processing that has been carried out to answer the research objectives. The company experienced an increase in storage costs because it did not take into account safety stock and did not choose a method that was not optimal. The company procures its inventory the use of Fixed Order Quantity with the order quantity of raw materials for making as much as 5000 pieces of pants per order.

Ordering technique (lot size) using two methods, namely the Silver Meal produces a total inventory cost that is smaller than the Wagner Whitin Algorithm except for zipper jeans small order interval with a frequency of ordering fabric pants six times, thread for fabric pants for three times, zipper fabric five times ordering, jeans fabric material times four ordering, jeans thread zipper two times and ordering jeans two times. Method Wagner Whitin The algorithm generates a total inventory cost that is higher than the Silver Meal but lower than the company's approach because to the small order interval with the frequency of ordering fabric four times for pants, fabric pants for two times ordering, zipper cloth pants ordered two times, jeans fabric material eight ordered times and jeans one time. As for the zipper of jeans, one order is made so that the costs incurred are smaller than the Silver Meal Method.

Companies can use both methods for each raw material. However, it is more optimal if the company utilizies only one method for the procurement of raw materials, namely the Silver Meal Method because when used in the long term, the costs incurred for the procurement of raw materials are lower than the Wagner Whitin Algorithm method. This research can be developed again at the shelf time of the material so that it can maximize the existing inventory so that there is no dead stock. For further research, it is necessary to add research objects and not focus on just 2 products so that the results obtained are more optimal for the company. because the more objects that are predicted, the smaller the percentage of forecast error.

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