

Ordering Size Optimization of Raw Material to Minimize Inventory Costs using Wagner-Within Algorithm and Silver-Meal Methods

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Abstract. Inventory is one of the current assets that can be classified as company assets. But in reality, inventory often turns into an operational problem that can affect the company's overall performance. This problem occurs due to the incorrect determination of the amount of inventory. Both excess and shortage of inventory can lead to cost overruns. This study applies the Wagner Whitin Algorithm and the Silver-Meal method in the lot-sizing process and the ABC (Always Better Control) method in determining the classification of raw materials at PT. X. Using the ABC method, it is known that the ADC-12 Ingot item has a very significant effect to inventory. Inventory optimization using the Wagner Whitin Algorithm and the Silver-Meal method resulted in the optimal frequency of ordering ADC-12 Ingots is 9 times and the total inventory cost is 994,098,000 IDR as well as inventory cost savings of around 18,403,180 IDR or 1.8% of the cost of existing inventory.

Keyword : *Inventory Costs, Wagner-Within Algorithm, Silver-Meal Methods*

1 Introduction

Inventory is one of the current assets that can be classified as company assets. But in reality, inventory often turns into an operational problem that can affect the company's overall performance. Lack of inventory can disrupt the production process and make inventory costs increase due to emergency procurement costs. Meanwhile, excess inventory can lead to excessively high storage and maintenance costs.

PT. XYZ is one of the subcontracting companies of automotive parts manufacturers. As a subcontracting company, PT. XYZ is very concerned about inventory issues that will affect the demand fulfillment which is one of the criteria required in partnership.

The company has no problems in meeting the demands of its business partners. However, the company feels the need to optimize raw material control. Based on observations in the company, it is known that in placing orders PT XYZ only consider the numbers of raw materials that can meet the needs for a certain period without considering the inventory costs incurred. This can lead to a buildup of raw materials and an increase in inventory costs.

This study applies the Wagner Whitin Algorithm and the Silver-Meal method in the lot-sizing process and the ABC (Always Better Control) method in determining the classification of PT XYZ raw materials. This study

is willing to provide the right solution to PT XYZ problems in determining the optimal order size of raw material procurement to minimize inventory cost.

2 Literature Review

Inventory management is the ability of a company to organize and manage its inventory to ensure availability both in stable and fluctuating market conditions. The types of inventory i.e office supplies inventory, raw materials inventory, work in process inventory, and inventory of finished goods. The goal of inventory management is to provide the right amount of material, the right lead time at a low cost. Thus, the right inventory level and the right ordering system are very important in saving the company's expenses and at the same time increasing the company's profits.

In this section, the method used in this study will be explained, which consists of the ABC method, the Wagner-Within Algorithm, and the Silver-Meal Algorithm.

2.1 ABC Method

The ABC method aims to classify all the inventory items into three categories based on their usage value [1]. Inventories with a high usage value (about 70%-80% or more) of the total inventory value with only 5-10% of

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the total items are classified in class A. Class B is a group of items with moderate usage value of inventory which includes 15% - 25% of the total inventory value and 10-20% of the total items. The last is inventory which has low usage values (5% - 10% of the total value of inventory) which consists of 70-80% of the total items that will be classified into class C. However, this proportion is not absolute because variations in prices and levels of use as well as management policies often lead to variations in the proportion, although it is still around this value.

According to Gaspersz [2] the procedure used to classify inventory into A, B, C, is as follows:

1. Determine inventory usage per item over a certain period
2. Calculate the total usage value of each item of inventory
3. Calculating the total usage value of inventory
4. Calculate the percentage of usage value of each item
5. Sort the percentage of usage values from the largest to the smallest
6. Classify items into categories A, B, or C

2.2 Wagner Whitin Algorithm

The Wagner Whitin algorithm is the optimum solution to the dynamic deterministic order size problem, where the requirements for each period must be met. The goal is to obtain an optimal ordering strategy for the entire demand schedule by minimizing total procurement costs and cost savings. This algorithm was developed by Wagner and Within in 1958 [3]. A problem is categorized as dynamic deterministic if the level of demand/need is known with certainty but the size varies from period to period. This algorithm calculates all possible ordering alternatives in meeting the demand for each period in the planning horizon so that it always gives the optimal answer. Kulkarni n Rajhans [1] compared several methods i.e Lot for Lot, Economic order Quantity, Period order quantity, Least unit cost, Least total cost, Least period cost, Wagner-Whitin Algorithm to find minimal inventory cost, and in all cases, the Wagner-Whitin model gives the minimum total annual inventory cost [4].

There are five steps in the Wagner-Whitin Algorithm:

1. Calculating Cumulative demand from the beginning of the period to the end of the period using formula (1).

$$Q_{c:e} = Q_{c:i} + Q_e \quad (1)$$

where $Q_{c:e}$ is the total number of demand for the entire period, $Q_{c:i}$ is the total number of demand from all previous periods, and Q_e is the number of demand in the intended period.

2. Calculating the total variable costs for all possible ordering alternatives in N periods. The total variable costs in period c to period e which consist of ordering costs and holding costs are represented as Z (formula 2).

$$Z_{c:e} = C + hP \sum_{i=c}^e (Q_{c:e} - Q_{c:i}) \quad (2)$$

for $1 < c < e < N$. Where :

C : ordering cost per order placement
 h : holding cost per unit per period
 P : unit price per item
 $Q_{c:e}$: total number of demand for the entire targeted period = $\sum_{i=e}^e R_{ki}$
 R_{ki} : demand in k^{th} period
 $Q_{c:i}$: demand in i period

3. Calculate the order combination that can minimize the cost, described by f_e as minimum cost at e period, the inventory level at the end of period e is zero. The step begins with $f_0 = 0$ then calculating f_1, f_2, \dots, f_N in those order combinations. Then calculating f_e using formula:

$$f_e = \text{Min} (Z_{c:e} + f_{c-1}) \text{ for } c = 1.2 \dots e \quad (3)$$

4. Define the optimal solution

2.3 Silver-Meal Algorithm

The Silver-Meal method was developed by Edward Silver and Harlan Meal based on the cost period [3]. Silver-Meal Algorithm is a heuristic approach to determine the purchase lot size which is relatively easy to use [5, 6]. The silver meal heuristic approach is similar to the EOQ approach, but in the calculation, it is based more on the variable cost of the purchasing period and not based on the total demand during the planning horizon [7, 8].

The steps of the Silver-Meal algorithm based on Asmal et al [3] are:

1. Calculating the average cost of inventory using formula (4).

$$\frac{TVC(T)}{T} = \frac{C + Ph \sum_{k=1}^T (k-1)D_k}{T} \quad (4)$$

Where:

C : ordering cost per order placement
 h : holding cost per unit per period
 P : unit price per item
 T : number of period
 D_k : demand in k period

This step is carried out in period 1 until the period that has the lowest average inventory cost is found. This period is the order period and the amount of orders is the total demand during that period.

2. Repeat step 1 until all have been evaluated and a procurement table is compiled

3 Methodology

This section will explain the calculation phase and the steps taken to get the order frequency and order size that can optimize the inventory costs of PT XYZ.

3.1 Raw Material Classification

Based on field data collection and observation, it is known that raw materials at PT XYZ are consist of Ingot ADC-12, Honda Metal Sleeper (MS), Yamaha MS, Vario MS, and Suzuki MS. The unit price of each item and the amount of usage or demand

within three months can be seen in Table 1. Using the data in Table 1, calculations are then carried out using the ABC method according to the procedure used in Gaspersz [2]. The results of the classification of raw materials are obtained in Table 1.

Ingot ADC-12s are in category A because they have a large percentage in fund absorptions, about 94.92%, with a small percentage of item types, which is only 20% of all items. Then for Honda MS, Suzuki MS, Yamaha MS, and Vario MS are classified as category C because the percentage of fund absorptions is very small, which is only 5% (combined) of the total fund absorptions with a large percentage of item types, which is 80%. Thus category A is a category of raw materials that has a very significant influence on the total cost of inventory. So, to optimize PT XYZ's inventory costs, it will focus only on optimizing the inventory of Ingot ADC-12.

Table 1. Demand and Raw Material Classification

Items Type	Units	Demand	Units Price (IDR)	Total Price (1000 IDR)
Ingot ADC-12	Kg	24.7596	26.000	6.437.496
Honda MS	Unit	3.213.900	100	321.390
Suzuki MS	Unit	85.000	110	9.350
Yamaha MS	Unit	70.000	110	7.700
Vario MS	Unit	40.000	150	6.000
Total				6.781.936
Items Type	Percentage of Fund Absorption	Percentage of Item Type	Item Category	
Ingot ADC-12	94,92%	20%	A	
Honda MS	4,74%	80%	C	
Suzuki MS	0,14%			
Yamaha MS	0,11%			
Vario MS	0,09%			
Total	100%	100%		

3.2 Existing Total Cost of Inventory Calculation

There are two basic variable costs in inventory, namely ordering costs and holding costs. Based on observations, the details of ordering cost components and storage cost components at PT XYZ are presented in Table 2.

Table 2. Ordering Cost Components and Holding Cost Components of Ingot ADC-12

Description		Details
Ordering Cost (C)		
1	Administrative costs	
	- Order File and Delivery Note	15.000 IDR
	- Telephone and Internet Fees	10.000 IDR
2	Loading and Unloading Labor Fee and Inspection Fee	225.000 IDR
Total Ordering Cost		250.000 IDR
Holding Cost (hP)		
1	Risk of Damage	0,25%P
2	Handling Fee	0,25%P
3	Storage Facility Fee	0,75%P
4	Cost of Physical Calculation and Consolidation of Reports	0,25%P
Total Holding Cost		1,5 %P

Where the value of "P" in the holding cost component is the unit price of Ingot ADC-12 item, which is 26,000 IDR.

In the existing condition, the procurement of the Ingots ADC-12 is carried out once a month at the beginning of the month to meet the demand for that month. The calculation of the inventory cost of Ingots ADC-12 from October to December 2018 can be seen in Table 3.

From Table 3 it can be seen that the existing total cost of inventory that must be incurred by PT XYZ for Ingots ADC-12 from October to December 2018 is 1,012,501,180 IDR, with a variable cost of 20,731,180 IDR.

Table 3. Total Existing Inventory Cost of Ingot ADC-12

Week	Receipt (Kg)	Demand (Kg)	Leftovers (Kg)	Ordering Cost (Rp)	Holding Cost (Rp)	Purchasing Cost (Rp)	Total Cost (Rp)
W-1 Oct	13.480	3.900	9.580	250.000	3.736.200	350.480.000	354.466.200
W-2 Oct		650	8.930	0	3.482.700	0	3.482.700
W-3 Oct		0	8.930	0	3.482.700	0	3.482.700
W-4 Oct		8.930	0	0	0	0	0
W-1 Nov	10.303	3.130	7.173	250.000	2.797.000	267.878.000	270.925.470
W-2 Nov		4.173	3.000	0	1.170.000	0	1.170.000
W-3 Nov		3.000	0	0	0	0	0
W-4 Nov		0	0	0	0	0	0
W-1 Dec	14.362	4.500	9.862	250.000	3.846.180	373.412.000	377.508.180
W-2 Dec		6302	3560	0	1.388.400	0	1.388.400
W-3 Dec		3360	200	0	78.000	0	78.000
W-4 Dec		200	0	0	0	0	0

Total	750.000	19.981.180	991.770.000	1.012.501.650
Variable Cost of Inventory	20.731.180			

3.3 Determination of Order Size using The Wagner Within Algorithm

Using formula number 2, the total variable costs can be calculated for all alternative orders that may occur in N periods and the results are shown in Table 4.

Table 4. Calculation of variable cost (Z_{ce}) Ingot ADC-12 (in 1000 IDR)

e \ n	1	2	3	4	5	6
1	250	504	504	10.952	15.834	23.972
2		250	250	7.215	10.878	17.387
3			250	3.733	6.174	11.057
4				250	1.471	4.726
5					250	1.877
6						250

e \ n	7	8	9	10	11	12
1	30.992	30.992	45.032	67.152	80.256	81.114
2	23.237	23.237	45.032	55.185	66.978	67.758
3	15.737	15.737	26.267	43.471	53.954	54.656
4	8.236	8.236	17.011	31.757	40.930	41.554
5	4.217	4.217	11.237	23.526	31.389	31.935
6	1.420	1.420	6.685	16.516	23.068	23.536
7	250	250	3.760	11.133	16.375	16.765
8		250	2.005	6.921	10.852	11.164
9			250	2.708	5.329	5.563
10				250	1.560	1.716
11					250	328
12						250

From the results of the Z_{ce} calculation in Table 4, then the combinations of orders that can minimize costs (f_e) are calculated with formula number 3, and the results are summarized in Table 5.

Table 5 Calculation of order combinations with minimum costs (f_e) of Ingot ADC-12 (in 1000 IDR)

e \ n	0	1	2	3	4	5	6
1		250	504	504	10.952	15.834	23.972
2			504	504	7.465	11.128	17.637
3				750	4.233	6.674	11.557
4					750	1.971	5.226
5						1.000	2.627
6							1.250
f_e	0	250	504	504	750	1.000	1.250

e \ n	7	8	9	10	11	12
1	30.992	30.992	45.032	67.152	80.256	81.114
2	23.237	23.237	45.282	55.435	67.228	68.008
3	16.237	16.237	26.767	43.971	54.454	55.156
4	8.736	8.736	17.511	32.257	41.430	42.054
5	4.967	4.967	11.987	24.276	32.139	32.685
6	2.420	2.420	7.685	17.516	24.068	24.536
7	1.500	1.500	5.010	12.383	17.625	18.015
8		1.750	3.505	8.421	12.352	12.664
9			1.750	4.208	6.829	7.063
10				2.000	3.310	3.466
11					2.250	2.328
12						2.500
f_e	1.500	1.500	1.750	2.000	2.250	2.328

From Table 5, it can be seen that the value of f_{12} is 2,328,000 IDR. This value is formed by adding $Z_{11:12}$ in Table 4 of 328,000 IDR and f_{10} of 2,000,000 IDR. This means that orders are placed in the 11th period (December W-3) to fulfill up to the 12th period (December W-4) demand of 3,560 kg. The summary of the number of orders can be seen in Table 6.

Table 6. Optimum Order Size and Cumulative Variable Cost Ingot ADC12 using the Wagner Whitin Algorithm

Period	1	2	3	4	5	6	7	8	9	10	11	12
Demand (Kg)	3,900	650	0	8,930	3,130	4,173	3,000	0	4,500	6,302	3,360	200
Order Size (Kg)	3,900	650	0	8,930	3,130	4,173	3,000	0	4,500	6,302	3,560	0

Cumulative variable cost (1,000 IDR)	250	500	500	750	1000	1.250	1.500	1.500	1.750	2.000	2.328	2.328
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Table 7. Optimum Order Size and Cumulative Variable Cost Ingot ADC12 using Silver Meal Algorithm

Periode	1	2	3	4	5	6	7	8	9	10	11	12
Demand (Kg)	3,900	650	0	8,930	3,130	4,173	3,000	0	4,500	6,302	3,360	200
Order Size (Kg)	4,550	0	0	8,930	3,130	4,173	3,000	0	4,500	6,302	3,560	0
Cumulative variable cost (1,000 IDR)	504	504	504	754	1.004	1.254	1.504	1.504	1.754	2.004	2.332	2.332

Based on Table 6, it is known that by applying the Wagner Whitin Algorithm to determine the optimum order size, the Ingot ADC-12 order frequency is 9 times and the total variable cost of inventory is 2,328,000 IDR.

3.4 Order Size Determination using The Silver-Meal Algorithm

The order size evaluation table can be seen in Table 7. In the 3rd period in Table 6, the lowest value of $TRC(T)/T$ occurred at the value of 168, so the demands of the 1st period to 3rd period were combined and order are placed in period 1 (Oct W-1) of 4550kg. Furthermore, the same evaluation is carried out for the rest of the periods.

Table 8. The Average Inventory Cost Calculation

Demand Period	Demand	carried period(T)	Holding Cost at T	Cumulative HC	Total Var Cost	$\frac{TRC(T)}{T}$
1	3.900	1	-	-	250	250
2	650	2	254	254	504	252
3	-	3	-	254	504	168
4	8.930	4	10.448	10.702	10.952	2.738
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11	3.360	1	.	.	250	250
12	200	2	78	78	328	164

From the calculation of the average variable costs in Table 7, a procurement table is arranged to shows the order placement and order size of the raw materials. The procurement table and cumulative variable cost of inventory using the Silver-Meal Algorithm can be seen in Table 8.

Based on Table 8, it is shown that by applying the Silver-Meal Algorithm the total variable cost of Ingot ADC-12 inventory is 2,332,000 IDR with 8 times order frequency.

4 Result and Discussion

After calculating the order size using the two proposed methods, namely the Wagner Whitin (WW) and the

Silver-Meal (SM) Algorithm, the inventory cost incurred can be compared as shown in Table 9.

In terms of inventory variable costs (ordering costs and holding costs) that affect the number of inventory costs, the proposed method, the Wagner-Whitin and Silver-Meal Algorithm results in savings of 18,403,650 IDR and 18,403,150 IDR compared to the existing variable costs or equal to 88.8%.

Table 9. Comparison of Variable Costs of Inventory Existing Condition and Proposed Method

	Existing (IDR)	WW (IDR)	SM (IDR)
Variable Cost	20,731,180	2,328,000	2,331,500
Saving (IDR)	0	18,403,650	18,400,150
Saving (%)	0%	88,8%	88,8%

Table 10. Comparison of Total Costs of Inventory Existing Condition and Proposed Method

	Existing (IDR)	WW (IDR)	SM (IDR)
Total Cost	1,012,501,650	994,098,000	994,101,500
Saving (IDR)	0	18,403,650	18,400,150
Saving (%)	0%	1.8176%	1.8173%

In terms of the total cost of inventory which includes the purchase cost as a fixed cost of inventory, the Wagner-Whitin and Silver-Meal Algorithm as the proposed method results in a savings of 18,403,650 IDR and 18,400,150 IDR or managed to save 1.8% of the total cost of existing inventory as shown in Table 10.

From these results, the proposed method of the Wagner-Whitin Algorithm is accepted and can be used as a reference for PT XYZ in planning and controlling their raw material inventories in the next period. And it can be concluded that the optimal order frequency for Ingot ADC-12 from October to December 2018 is nine times to save 1.8% of the total existing inventory costs.

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