Material Requirement Planning on Y-Strainer Production (Case Study at PT. XYZ)

Natalia Velony Putri and Lina Gozali
Department of Industrial Engineering, Faculty of Engineering
Universitas Tarumanagara
Jl. Letjen S. Parman No. 1, Jakarta 11440, Indonesia
natalia.545180020@stu.untar.ac.id, linag@ft.untar.ac.id

Abstract

Industrialization is growing rapidly in line with increasing needs from consumers, making competitions stronger. To continue developing and competing with competitors, a company must increase the productivity in order to meet consumer needs. PT. XYZ produces metal fitting products with make-to-order principle. This study aims to plan and control the number of raw materials used in production to minimize costs without reducing the quality of the products. The Material Requirement Planning (MRP) method is recommended because it can help raw material procurement to be more effective and efficient. Moreover, implementing safety stock system anticipates sudden fluctuations in demand. Thus, the company will not lose the opportunity to meet consumer needs as scheduled in the first place with minimum possible cost. In this case, the use of MRP method with Wagner Within Algorithm (AWW) lot-sizing technique will result in the lowest costs compared to Economic Order Quantity (EOQ), Period Order Quantity (POQ), Lot for Lot (LFL), Silver Meal Algorithm, and Least Unit Cost (LUC). Using the AWW lot-sizing, the order and storage costs of raw materials will be saving Rp1,285,135 with a percentage of 19% compared to the usual method PT. XYZ usually used.

Keywords
Forecasting, Safety Stock, Material Requirement Planning, Wagner Within Algorithm, Metal Fitting

1. Introduction

Industrialization is growing rapidly in line with increasing needs from consumers, making competitions stronger. To continue developing and competing with competitors, a company must increase the productivity in order to meet consumer needs. Therefore, all departments in a company must collaborate to achieve the company's vision and mission. One of the divisions that plays an important role in a manufacturing company is PPIC, which regulates the course of production to run optimally and achieve production targets in accordance with the production planning that has been made.

In production activities, of course, it is necessary to plan and control raw materials where raw materials are one of the most important aspects in the procurement of a product. Raw material requirement planning has to be made based on accurate demand forecasting in order to become increase productivity. Increasing needs and demand from customers prompt a company to improve their raw material planning. Hence, every company must have a strategy to plan and control the number of raw materials to minimize costs without reducing the quality of the products. In addition, planning and controlling raw materials are needed to prevent shortages due to delays in raw materials that will hinder the production process or accumulation due to excess raw materials.

PT. XYZ is a manufacturing company that produces metal fitting products with the principle of make-to-order; that is what makes the availability of raw materials very important. The products made in this company are valves, strainers, drainer, and others. The products sold are of high quality at competitive prices. In fulfilling customers demand with high quality, PT. XYZ imports raw materials from abroad. Those raw materials used to produce high quality products are Bronze Ingots, Nickel Bronze Ingots, and Silicone Ingots imported from China, Korea, and Taiwan. Therefore, the observation done on the method of planning and controlling raw materials used by PT. XYZ is a form of learning and improvement on the method of ordering raw materials.

In terms of the procurement of raw materials, PT. XYZ orders raw materials according to the production needs of all ordered products or based on the demand forecast that the PPIC department has calculated. Procurement of raw materials will run smoothly if the delivery goes well. The problem that occurred in PT. XYZ is tardiness of raw materials arrival that is caused by shipping problem such as constraints at the port, that can hinder production activities and leads to delayed arrival of customer products. Thereof, this research can help the material procurement of the company to be more effective and efficient so that the customer products arrive in the customers' hand as scheduled in the first place.

1.1 Objectives

This study aims to plan and control raw material supplies to be more effective and efficient with the Material Requirement Planning (MRP) method and implement safety stock system to anticipate sudden fluctuations in demand. Thus, the company will not lose the opportunity to meet consumer needs as scheduled in the first place with minimum possible cost.

2. Literature Review

2.1 Forecasting

Forecasting is the process of estimating the future needs to come, including the size of quantity, time, and location to fulfil the demand for product or services (Nasution and Yudha, 2008). The best suitable forecast method is the one with the smallest error. Having upcoming demand can help the company decides which strategy is the most suitable for the next planning period (Gozali et al., 2013).

1. Single Moving Average (SMA)

$$F_{t+m} = \frac{\sum_{i=1}^{t-N+1} Xi}{N} \quad (1)$$

Remarks:
F_{t+m} : forecasting value for t + m period
X_i : observation data in t period
N : serial length of time

2. Double Moving Average (DMA)

$$F_{t+m} = a_t + b_m \quad (2)$$
$$a_t = S'_t + (S'_t - S"_t) \quad (3)$$
$$b_t = \frac{2}{N-1}(S'_t - S"_t) \quad (4)$$

Remarks:
F_{t+m} : forecasting data for m period ahead
S'_t : first moving average in t period
$S"_t$: second moving average in t period
m : number of periods ahead to forecast

3. Weighted Moving Average (WMA)

$$F_{t+1} = \frac{(W_t.X_t)+(W_{t-1}.X_{t-1}) + ...+ (W_{t-N+1}.X_{t-N+1})}{W_t+W_{t-1}+ ....+W_{t-N+1}} \quad (5)$$

Remarks:
F_{t+1} : forecasting for t + 1 period
W_t : weight for t period
N : total period

4. Single Exponential Smoothing (SES)

$$F_{t+1} = (a.Xt) + (1-a) \quad (6)$$

Remarks:
F_t : forecasting for t period
F_{t+1} : forecasting for t + 1 period
a : smoothing constant
X_t : demand data in t period

5. Double Exponential Smoothing (DES)

$$F_{t+m} = a_t + (b_t.m) \quad (7)$$
$$S'_t = (\alpha.X_t) + (1-\alpha) \times S'_{t-1} \quad (8)$$
$$S"_t = (\alpha.X_t) + (1-\alpha)S"_{t-1} \quad (9)$$
$$a_t = 2S'_t - S"_t \quad (10)$$
$$b_t = \frac{\alpha\,(S'_t - S"_t)}{1-\alpha} \quad (11)$$

Remarks:
F_{t+m} : forecasting data for m period ahead
S'_t : single exponential smoothing value in t period
$S"_t$: double exponential smoothing value in t period

m : number of periods ahead to forecast
α : exponential smoothing parameter ($0 < \alpha < 1$)

6. Linear Regression

$$Y'(t) = a + b(t) \quad (12)$$

$$b = \frac{n \sum x\, y - \sum x \sum y}{n \sum x^2 - (\sum x)^2} \quad (13)$$

$$c = \frac{\sum y - b \sum t}{n} \quad (14)$$

7. Cyclic

$$Y = a + b \sin\left(\frac{2\pi t}{n}\right) + c \cos\left(\frac{2\pi t}{n}\right) \quad (15)$$

$$a = \frac{\sum Y(t)}{N} \quad (16)$$

$$b = \frac{\sum Y(t) sin\left(\frac{2\pi t}{n}\right)}{N} \quad (17)$$

$$c = \frac{\sum Y(t) cos\left(\frac{2\pi t}{n}\right)}{N} \quad (18)$$

8. Quadratic Regression

$$Y'(t) = a + bt + ct^2 \quad (19)$$

$$b = \frac{\gamma\delta - \theta\alpha}{\gamma\beta - \alpha^2} \quad (20)$$

$$c = \frac{\theta - b\alpha}{\gamma} \quad (21)$$

$$a = \frac{\sum Y(t) - b \sum t - c \sum t^2}{n} \quad (22)$$

Comparison among some of the forecasting methods is done using Mean Error (ME), Mean Absolute Deviation (MAD), Sum of Squared Error (SSE), Mean Square Error (MSE), Standard Deviation of Error (SDE), Mean Percent Error (MPE), and Mean Absolute Percent Error (MAPE) (Gasperz, 2004). In testing those forecasting methods, the equation is as follows.

1. Mean Error (ME)

$$ME = \left| \sum_{i=1}^{N} \frac{Xi - Fi}{N} \right| \quad (23)$$

2. Mean Absolute Deviation (MAD)

$$MAD = \sum_{i=1}^{N} \frac{|Xi - Fi|}{N} \quad (24)$$

3. Sum of Squared Error (SSE)

$$SSE = (Xi - Fi)^2 \quad (25)$$

4. Mean Square Error (MSE)

$$MSE = \sum_{i=1}^{N} \frac{(Xi - Fi)^2}{N} \quad (26)$$

5. Standard Deviation of Error (SDE)

$$SDE = \sum_{i=1}^{N} \frac{(Xi - Fi)^2}{N-1} \quad (27)$$

6. Mean Percent Error (MPE)

$$MPE = \frac{100 \sum_{i=1}^{N} \frac{(Xi - Fi)}{Xi}}{N} \quad (28)$$

7. Mean Absolute Percent Error (MAPE)

$$MAPE = \frac{100 \sum_{i=1}^{N} \frac{|Xi - Fi|}{Xi}}{N} \quad (29)$$

Remarks:
X_i : demand data in i period
F_i : forecasting for i period

2.2 Safety Stock

Safety stock is additional inventory that is held to maintain the risk of the inventory shortage or also called stock out (Assauri, 1993:242). The safety stock formula is as follows.

$$\textit{Safety stock} = Z \times \sigma_D \times \sqrt{L} \quad (30)$$

Remarks:
Z : safety factor

σ_D : standard deviation of demand
L : lead time

2.3 Material Requirement Planning (MRP)

MRP is a technique that uses a list of material requirements, inventory, estimated revenue, and master production schedule to determine material requirements (Heizer and Render, 2009:648). Material requirement planning can reduce lead time, inventory cost, improve inventory management and manufacturing efficiency and effectiveness by using accurate production planning (Herjanto, 2009:275). The formulas that are used in this calculation are as follows.

1. Economic Order Quantity (EOQ)
   EOQ is an inventory level that minimizes the total cost of storing inventory and ordering costs with fixed lot size (Herjanto, 2009).

$$EOQ = \sqrt{\frac{2DS}{H}} \quad \text{.......} (31)$$

   Remarks:
   D : raw material quantity needed
   S : order costs
   H : storage costs

2. Period Order Quantity (POQ)
   POQ is a technique that uses the concept of EOQ so that it can be used in discrete or multiple demand periods. This technique uses the logic of EOQ to get quantity order that must be made for the interval of order period in one period (Hansa, 2015).

$$EOI = \frac{EOQ}{R} = \sqrt{\frac{2C}{RPh}} \quad \text{.......} (32)$$

   Remarks:
   EOI : economic order interval
   C : order costs
   H : storage costs percentage
   P : material cost per unit
   R : average demand

3. Lot for Lot (LFL)
   LFL or minimum inventory method is a technique that provides inventory in accordance with the needs at that time with the result that the only incurred cost is the ordering cost. By using LFL, if there is a delay in delivering goods, it will delay the production process (Diana, 2013).

4. Silver Meal Algorithm
   Silver Meal is a technique that aims to minimize the total cost of inventory per period. The criterion of this technique is that the lot size chosen must minimize the total cost per period. Demands with successive periods are accumulated into a tentative lot size until the total carrying cost and setup cost of the lot divided by the number of periods involved increase (Gozali et al., 2013). The total relevant cost per period is calculated using the following formula.

$$\frac{TRC(T)}{T} = \frac{C + Total\ storage\ cost\ until\ T\ period}{T}$$

$$\frac{TRC(T)}{T} = \frac{C + Ph\sum(K-1)Rk}{T} \quad \text{.......} (33)$$

   Remarks:
   C : order costs
   H : storage costs percentage
   P : material cost per unit
   Ph : storage costs
   TRC(T) : the total relevant cost in T period
   T : additional time in the period
   Rk : the average demand during k period

5. Least Unit Cost (LUC)
   LUC is a lot-sizing technique that choose the lowest cost per unit from certain periods by adding up total storage cost to ordering cost and then finding out the period with the lowest unit cost (Nisa, 2016). In the

LUC technique, the size of the order quantity is determined by trial and error, namely by asking whether the lot size in one period should be the same as the net size or it is added to the next period. In the end, the decision is determined as per the lowest unit cost (sum of order and storage cost per unit) of each proposed lot size to be selected.

$$V(L) = \frac{s+(h\sum_{t=T}^{L}[(t-dT)dt]}{J} \quad \text{...} (34)$$

Remarks:

s : order costs
h : storage costs
dt : quantity needs in t period
T : the first period the cumulative lot has been calculated
L : the last period which needs to be cumulative lot included
l : a cumulative lot each period
t : N period

6. Wagner Within Algorithm (AWW)
AWW is a lot-sizing technique that minimizes inventory costs by using a variable cost matrix step (Gozali et al., 2013). This technique aims to obtain the optimal solution for a deterministic number of ordering units over a predetermined time horizon (Tersine, 1994). The optimization procedure of this technique is based on a dynamic program to obtain the optimal order size of the entire required schedule by minimizing the order and storage total costs. Basically, this technique tests all possible ordering methods to meet the net needs of each period that is on the planning horizon so as to provide the optimal answer. (Heizer and Render, 2011)

3. Methods

First of all, an observation is done by doing field study to find out the actual problems that occurred. On the other hand, the literature review is also be done. After determining the problem, the purpose of the research is identified. Following that, the data is collected to be processed afterwards, so that in the end, the result could be analyzed.

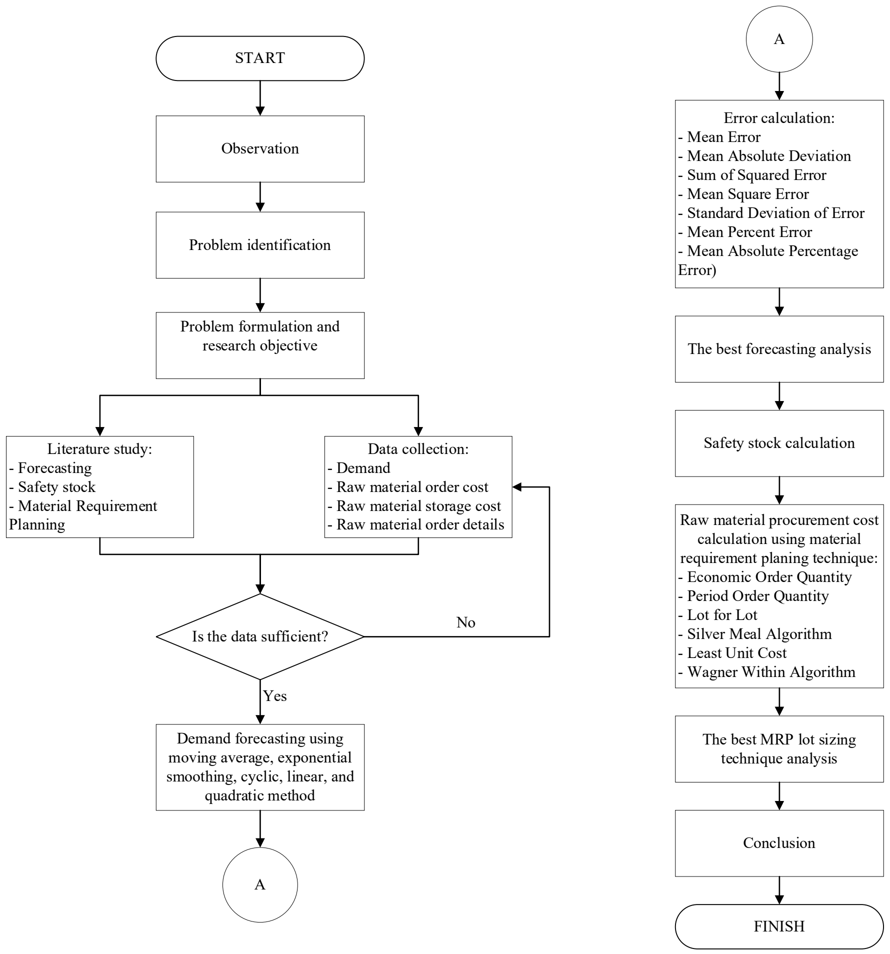

Figure 1. Research Methodology Flowchart

The methods used to obtain a suitable production plan for PT. XYZ are forecasting, safety stock, and material requirement planning. In determining forecasting method according to the time series method, it is necessary to determine the type of data pattern. Constant (stationary), seasonal, and trend are three well-known data patterns. The constant pattern is found when values fluctuate around a constant average. This type is the one in which product sales do not increase or decrease due to time. A seasonal pattern is found when the series is affected by seasonal factors. When there is a tendency for data to increase or decrease, a trend pattern will be found. Forecasting is done by using SMA (Single Moving Average), DMA (Double Moving Average), and WMA (Weighted Moving Average) with moving average of 3 months, 4 months, and 5 months, respectively for each method; SES (Single Exponential Smoothing) and DES (Double Exponential Smoothing) with $\alpha = 0.1, 0.3, 0.5, 0.7, 0.9$, respectively for each method; also using cyclic, linear, and quadratic method. The best forecasting method is determined based on ME (Mean Error), MAD (Mean Absolute Deviation), SSE (Sum of Squared Error), MSE (Mean Square Error), SDE (Standard Deviation of Error), MPE (Mean Percent Error), and MAPE (Mean Absolute Percent Error).

Material requirement planning lot-sizing techniques used in this observation are EOQ, POQ, LFL, Silver Meal Algorithm, LUC, and AWW. The research methodology flowchart is shown in Figure 1.

4. Data Collection

Data used in this research are product demand data from March 2020 until February 2021, order lead time and cost components namely order and storage cost. All of the data that has been collected from PT. XYZ is shown in Table 1 and Table 2.

Table 1. Y-Strainer Demand Data

Period	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Quantity	136	388	726	96	100	15	32	288	192	346	832	580

Table 2. Y-Strainer Component Cost

No.	**Raw Material**	**Order Costs**	**Storage Costs**	**Buying Description**	**Order Frequency**	**Total Cost**
1	Imported Bronze Ingot 81%	Rp300,000	Rp75,000	Per Ton	3	Rp1,125,000
2	Local Bronze Gram 81%	Rp15,000	Rp3,750	Per Ton	1	Rp 18,750
3	Seal Tape	Rp15,000	Rp3,750	Per 300 Roll	4	Rp 75,000
4	Gasket	Rp15,000	Rp3,750	Per 10 Roll	1	Rp 18,750
5	Mesh 20 Filter	Rp350,000	Rp87,500	Per 300 Pcs	13	Rp5,687,500
Total Cost						**Rp6,925,000**

5. Result and Discussion

5.1 Forecasting Result

The most suitable forecasting method can be done by calculating the error of each method and choosing one of those with the smallest error. Based on the forecasting error calculation, the smallest error for Y-Strainer production in PT. XYZ is the cyclic method. All of the forecasting error calculation for the Y-Strainer product is summarized and shown in Table 3.

The best method in forecasting Y-Strainer product that is chosen is cyclic method, therefore, this method is represented to do demand projecting for the upcoming year. The result of the forecasting above is shown in Table 4.

Table 3. Forecasting Error Summary for Y-Strainer Product

Method	ME	MAD	SSE	MSE	SDE	MPE	MAPE
SMA (MA = 3 Months)	24.444	236.444	701082.000	77898.000	296.033	271.045	329.575
SMA (MA = 4 Months)	69.250	257.250	707070.000	88383.750	317.821	333.551	405.178
SMA (MA = 5 Months)	113.286	258.143	684651.000	97807.286	337.799	327.543	402.398
DMA (MA = 3 Months)	75.429	199.460	405608.543	57944.078	260.003	443.805	468.168
DMA (MA = 4 Months)	40.900	211.250	358964.664	71792.933	299.568	10.557	39.928
DMA (MA = 5 Months)	197.827	337.293	492175.406	164058.469	496.072	28.581	52.627
WMA (MA = 3 Months)	12.333	209.444	661979.000	73553.222	287.658	200.682	248.855
WMA (MA = 4 Months)	16.875	253.188	554892.000	17340.375	133.790	59.033	74.321
WMA (MA = 5 Months)	25.452	250.742	540623.000	17439.452	134.241	59.997	76.158
SES (α = 0.1)	137.636	239.273	1010778.000	91888.909	317.927	139.627	207.252
SES (α = 0.3)	97.182	244.091	943445.000	85767.727	307.155	180.118	243.549
SES (α = 0.5)	77.545	232.273	908953.000	82632.091	301.488	157.547	217.718
SES (α = 0.7)	60.727	228.545	904350.000	82213.636	300.724	120.505	177.683
SES (α = 0.9)	46.364	230.727	942272.000	85661.091	306.964	93.202	152.839
DES (α = 0.1)	89.200	240.000	892268.000	81115.273	314.866	209.832	264.272
DES (α = 0.3)	41.100	248.700	932489.000	84771.727	321.885	203.649	259.752
DES (α = 0.5)	11.500	257.900	1061709.000	96519.000	343.464	82.684	183.122
DES (α = 0.7)	17.400	287.200	1363066.000	123915.091	389.168	2.022	210.498
DES (α = 0.9)	40.600	340.600	1883438.000	171221.636	457.461	23.628	227.116
Cyclic	0.083	195.583	674253.000	56187.750	124.580	260.896	29.570
Linear	0.500	205.500	732510.000	61042.500	258.054	258.829	290.444
Quadratic	5136319.917	5136319.917	428355237137973.000	35696269761497.700	6240303.293	5219167.742	5219167.742

Table 4. Y-Strainer Product Forecast Using Cyclic Method

Period	1	2	3	4	5	6	7	8	9	10	11	12
Quantity	153	401	377	153	401	379	154	401	379	154	401	379

5.2 Bill of Material (BOM)

Bill of material shows structured list and the quantity of each component and material required to produce an item. BOM tree of Y-Strainer product is shown in Figure 2.

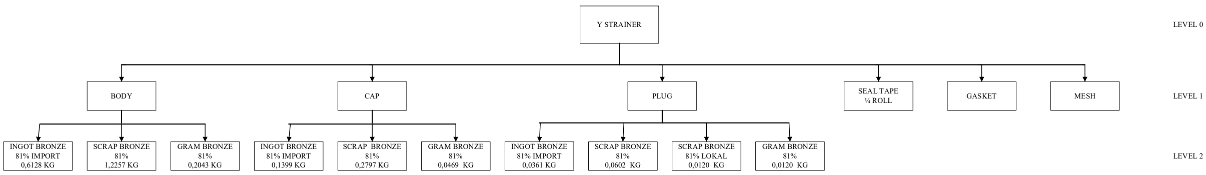

Figure 2. Bill of Material Tree of Y-Strainer

5.3 Safety Stock

Safety stock is carried out on all raw materials that will be turned into stock and calculated by the formula (30). The result of safety stock for each raw material of the Y Strainer product is shown in Table 5.

Table 5. Safety Stock for Y-Strainer Raw Material

Raw Material	Z-Table (90%)	*Lead Time* (day)	*Lead Time* (month)	Average Demand	Standard Deviation of Demand	Safety Stock
Imported Bronze Ingot 81%	1.28	18	0.600	0.245	0.092	1
Local Bronze Gram 81%		1	0.033	0.004	0.001	1
Seal Tape		1	0.033	77.750	29.179	7
Gasket		1	0.033	0.622	0.233	1
Mesh 20 Filter		15	0.500	311.000	116.718	106

5.4 Material Requirement Planning (MRP)

Based on the comparison of some lot-sizing techniques, AWW is the best technique because it has the least cost needed. This is also supported by the fact that the objective of AWW technique is to minimize the order and storage total costs. Comparison of the cost needed for each Y-Strainer raw material of all lot-sizing techniques is represented in graphics as shown in Figure 3 and Table 6.

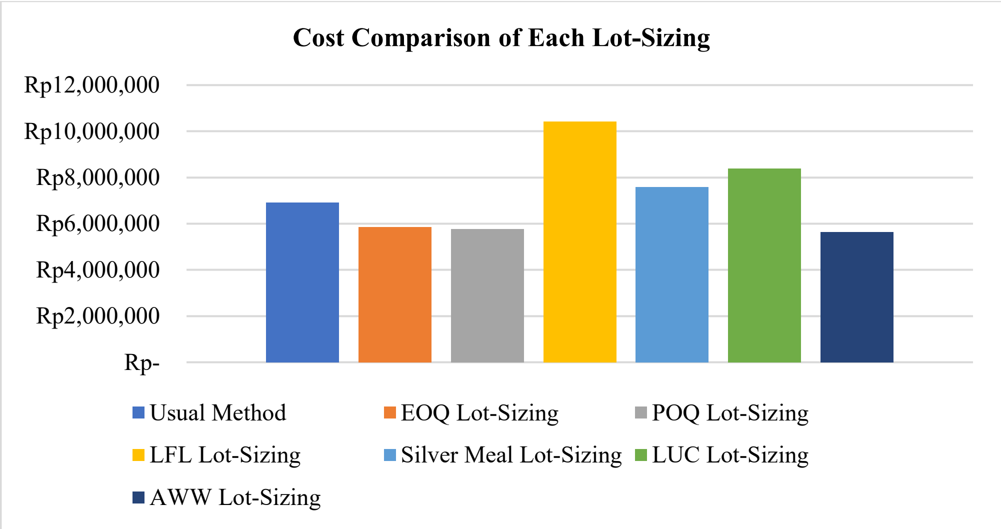

Figure 3. Cost Comparison of Each Lot-Sizing

Table 6. Cost Comparison of Each Lot-Sizing

Raw Material	Raw Material Procurement Cost Using Usual Method	Raw Material Procurement Cost Using EOQ Lot-Sizing	Raw Material Procurement Cost Using POQ Lot-Sizing	Raw Material Procurement Cost Using LFL Lot-Sizing
Imported Bronze Ingot 81%	Rp1,125,000	Rp 375,000	Rp 375,000	Rp 4,500,000
Local Bronze Gram 81%	Rp 18,750	Rp 18,750	Rp 18,750	Rp 225,000
Seal Tape	Rp 75,000	Rp 187,500	Rp 112,500	Rp 225,000
Gasket	Rp 18,750	Rp 18,750	Rp 18,750	Rp 225,000
Mesh 20 Filter	Rp5,687,500	Rp5,250,000	Rp5,250,000	Rp 5,250,000
Total Cost	**Rp6,925,000**	**Rp5,850,000**	**Rp5,775,000**	**Rp10,425,000**

Table 6. (cont'd) Cost Comparison of Each Lot-Sizing

Raw Material	Raw Material Procurement Cost Using Silver Meal Lot-Sizing	Raw Material Procurement Cost Using LUC Lot-Sizing	Raw Material Procurement Cost Using AWW Lot-Sizing
Imported Bronze Ingot 81%	Rp1,949,187	Rp2,672,787	Rp1,158,648
Local Bronze Gram 81%	Rp 26,334	Rp 76,886	Rp 15,965
Seal Tape	Rp 225,000	Rp 225,000	Rp 180,000
Gasket	Rp 129,510	Rp 510,883	Rp 85,253
Mesh 20 Filter	Rp5,250,000	Rp5,250,000	Rp4,200,000
Total Cost	**Rp7,580,031**	**Rp8,735,556**	**Rp5,639,865**

Therefore, by using the AWW lot-sizing, the procurement costs will be saving Rp1,285,135 with a percentage of 19% compared to the method PT. XYZ usually used. The result of AWW calculation for each material is shown in Table 7 until Table 11.

Table 7. MRP of Imported Bronze Ingot 81% Using AWW Lot-Sizing Technique (cost in thousands)

Imported Ingot Bronze 81%												
Safety Stock = 1												
Lead Time = 18 days												
Period	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Demand	0.121	0.316	0.297	0.121	0.316	0.299	0.121	0.316	0.299	0.121	0.316	0.299
Projected on Hand	2.471	2.155	1.857	1.737	1.420	1.121	1	1.420	1.121	1	1.299	1
Planned Order Receipt	2.592							0.737			0.615	
Planned Order Release	2.592							0.737			0.615	
Period Receipt	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	Rp 300.00	Rp 323.72	Rp 368.33	Rp 395.48	Rp 490.38	Rp 602.49	Rp 657.15	Rp 823.21	Rp 1,002.58	Rp 1,084.58	Rp 1,321.81	Rp 1,568.45
2		Rp 600.00	Rp 622.30	Rp 640.41	Rp 711.58	Rp 801.26	Rp 846.82	Rp 989.15	Rp 1,146.11	Rp 1,218.99	Rp 1,432.50	Rp 1,656.72
3			Rp 623.72	Rp 632.77	Rp 680.22	Rp 747.49	Rp 783.93	Rp 902.54	Rp 1,037.07	Rp 1,100.85	Rp 1,290.63	Rp 1,492.43
4				Rp 668.33	Rp 692.05	Rp 736.90	Rp 764.23	Rp 859.12	Rp 971.23	Rp 1,025.89	Rp 1,191.95	Rp 1,371.33
5					Rp 695.48	Rp 717.91	Rp 736.13	Rp 807.30	Rp 896.98	Rp 942.54	Rp 1,084.88	Rp 1,241.83
6						Rp 790.38	Rp 799.49	Rp 846.93	Rp 914.20	Rp 950.64	Rp 1,069.26	Rp 1,203.79
7							Rp 902.49	Rp 926.21	Rp 971.05	Rp 998.38	Rp 1,093.28	Rp 1,205.38
8								Rp 957.15	Rp 979.57	Rp 997.79	Rp 1,068.96	Rp 1,158.65
9									Rp 1,107.30	Rp 1,116.41	Rp 1,163.85	Rp 1,231.12
10										Rp 1,196.98	Rp 1,220.71	Rp 1,265.55
11											Rp 1,242.54	Rp 1,264.96
12												Rp 1,368.96
Minimum	Rp 300.00	Rp 323.72	Rp 368.33	Rp 395.48	Rp 490.38	Rp 602.49	Rp 657.15	Rp 807.30	Rp 896.98	Rp 942.54	Rp 1,068.96	Rp 1,158.65

Table 8. MRP of Local Bronze Gram 81% Using AWW Lot-Sizing Technique (cost in thousands)

Local Bronze Gram 81%												
Safety Stock = 1												
Lead Time = 1 day												
Period	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Demand	0.002	0.005	0.005	0.002	0.005	0.005	0.002	0.005	0.005	0.002	0.005	0.005
Projected on Hand	1.043	1.038	1.034	1.032	1.027	1.022	1.021	1.016	1.011	1.009	1.005	1
Planned Order Receipt	1.045											
Planned Order Release	1.045											
Period Receipt	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	Rp 15.00	Rp 15.02	Rp 15.05	Rp 15.07	Rp 15.14	Rp 15.23	Rp 15.27	Rp 15.40	Rp 15.53	Rp 15.60	Rp 15.78	Rp 15.96
2		Rp 30.00	Rp 30.02	Rp 30.03	Rp 30.08	Rp 30.15	Rp 30.19	Rp 30.30	Rp 30.42	Rp 30.47	Rp 30.63	Rp 30.80
3			Rp 30.02	Rp 30.02	Rp 30.06	Rp 30.11	Rp 30.14	Rp 30.23	Rp 30.33	Rp 30.38	Rp 30.53	Rp 30.68
4				Rp 30.05	Rp 30.07	Rp 30.10	Rp 30.12	Rp 30.20	Rp 30.28	Rp 30.32	Rp 30.45	Rp 30.59
5					Rp 30.07	Rp 30.09	Rp 30.10	Rp 30.16	Rp 30.23	Rp 30.26	Rp 30.37	Rp 30.49
6						Rp 30.14	Rp 30.15	Rp 30.19	Rp 30.24	Rp 30.27	Rp 30.36	Rp 30.46
7							Rp 30.23	Rp 30.25	Rp 30.28	Rp 30.30	Rp 30.38	Rp 30.46
8								Rp 30.27	Rp 30.29	Rp 30.30	Rp 30.36	Rp 30.42
9									Rp 30.40	Rp 30.40	Rp 30.44	Rp 30.49
10										Rp 30.53	Rp 30.55	Rp 30.59
11											Rp 30.60	Rp 30.61
12												Rp 30.78
Minimum	Rp 15.00	Rp 15.02	Rp 15.05	Rp 15.07	Rp 15.14	Rp 15.23	Rp 15.27	Rp 15.40	Rp 15.53	Rp 15.60	Rp 15.78	Rp 15.96

Table 9. MRP of Seal Tape Using AWW Lot-Sizing Technique (cost in thousands)

Seal Tape												
Safety Stock = 7												
Lead Time = 1 day												
Period	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Demand	38.25	100.25	94.25	38.25	100.25	94.75	38.5	100.25	94.75	38.5	100.25	94.75
Projected on Hand	7	7	7	7	7	7	7	7	7	7	7	7
Planned Order Receipt	45.25	100.25	94.25	38.25	100.25	94.75	38.5	100.25	94.75	38.5	100.25	94.75
Planned Order Release	45.25	100.25	94.25	38.25	100.25	94.75	38.5	100.25	94.75	38.5	100.25	94.75
Period Receipt	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	Rp 15.00	Rp 390.94	Rp1,097.81	Rp1,528.13	Rp3,031.88	Rp4,808.44	Rp5,674.69	Rp8,306.25	Rp11,148.75	Rp12,448.13	Rp16,207.50	Rp20,115.94
2		Rp 30.00	Rp 383.44	Rp 670.31	Rp1,798.13	Rp3,219.38	Rp3,941.25	Rp6,196.88	Rp 8,684.06	Rp 9,839.06	Rp13,222.50	Rp16,775.63
3			Rp 45.00	Rp 188.44	Rp 940.31	Rp2,006.25	Rp2,583.75	Rp4,463.44	Rp 6,595.31	Rp 7,605.94	Rp10,613.44	Rp13,811.25
4				Rp 60.00	Rp 435.94	Rp1,146.56	Rp1,579.69	Rp3,083.44	Rp 4,860.00	Rp 5,726.25	Rp 8,357.81	Rp11,200.31
5					Rp 75.00	Rp 430.31	Rp 719.06	Rp1,846.88	Rp 3,268.13	Rp 3,990.00	Rp 6,245.63	Rp 8,732.81
6						Rp 90.00	Rp 234.38	Rp 986.25	Rp 2,052.19	Rp 2,629.69	Rp 4,509.38	Rp 6,641.25
7							Rp 105.00	Rp 480.94	Rp 1,191.56	Rp 1,624.69	Rp 3,128.44	Rp 4,905.00
8								Rp 120.00	Rp 475.31	Rp 764.06	Rp 1,891.88	Rp 3,313.13
9									Rp 135.00	Rp 279.38	Rp 1,031.25	Rp 2,097.19
10										Rp 150.00	Rp 525.94	Rp 1,236.56
11											Rp 165.00	Rp 520.31
12												Rp 180.00
Minimum	Rp 15.00	Rp 30.00	Rp 45.00	Rp 60.00	Rp 75.00	Rp 90.00	Rp 105.00	Rp 120.00	Rp 135.00	Rp 150.00	Rp 165.00	Rp 180.00

Table 10. MRP of Gasket Using AWW Lot-Sizing Technique (cost in thousands)

Gasket												
Safety Stock = 1												
Lead Time = 1 day												
Period	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Demand	0.306	0.802	0.754	0.306	0.802	0.758	0.308	0.802	0.758	0.308	0.802	0.758
Projected on Hand	3.664	2.862	2.108	1.802	1	2.110	1.802	1	2.110	1.802	1	1
Planned Order Receipt	3.97					1.868			1.868			0.758
Planned Order Release	3.97					1.868			1.868			0.758
Period Receipt	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	Rp 15.00	Rp 18.01	Rp 23.66	Rp 27.11	Rp 39.14	Rp 53.35	Rp 60.28	Rp 81.33	Rp 104.07	Rp 114.47	Rp 144.54	Rp 175.81
2		Rp 30.00	Rp 32.83	Rp 35.12	Rp 44.15	Rp 55.52	Rp 61.29	Rp 79.34	Rp 99.23	Rp 108.47	Rp 135.54	Rp 163.97
3			Rp 33.01	Rp 34.16	Rp 40.17	Rp 48.70	Rp 53.32	Rp 68.36	Rp 85.41	Rp 93.50	Rp 117.56	Rp 143.14
4				Rp 38.66	Rp 41.67	Rp 47.36	Rp 50.82	Rp 62.85	Rp 77.06	Rp 83.99	Rp 105.05	Rp 127.79
5					Rp 42.11	Rp 44.95	Rp 47.26	Rp 56.28	Rp 67.65	Rp 73.43	Rp 91.47	Rp 111.37
6						Rp 54.14	Rp 55.29	Rp 61.31	Rp 69.83	Rp 74.45	Rp 89.49	Rp 106.55
7							Rp 59.95	Rp 62.96	Rp 68.64	Rp 72.11	Rp 84.14	Rp 98.35
8								Rp 62.26	Rp 65.10	Rp 67.41	Rp 76.43	Rp 87.80
9									Rp 71.28	Rp 72.44	Rp 78.45	Rp 86.98
10										Rp 80.10	Rp 83.11	Rp 88.79
11											Rp 82.41	Rp 85.25
12												Rp 91.43
Minimum	Rp 15.00	Rp 18.01	Rp 23.66	Rp 27.11	Rp 39.14	Rp 44.95	Rp 47.26	Rp 56.28	Rp 65.10	Rp 67.41	Rp 76.43	Rp 85.25

Table 11. MRP of Mesh 20 Filter Using AWW Lot-Sizing Technique (cost in thousands)

Mesh 20 Filter												
Safety Stock = 106												
Lead Time = 18 days												
Period	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Demand	153	401	377	153	401	379	154	401	379	154	401	379
Projected on Hand	106	106	106	106	106	106	106	106	106	106	106	106
Planned Order Receipt	259	401	377	153	401	379	154	401	379	154	401	379
Planned Order Release	259	401	377	153	401	379	154	401	379	154	401	379
Period Receipt	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	Rp 350	Rp 35,438	Rp 101,413	Rp 141,575	Rp 281,925	Rp 447,738	Rp 528,588	Rp 774,200	Rp1,039,500	Rp1,160,775	Rp1,511,650	Rp1,876,438
2		Rp 700	Rp 33,688	Rp 60,463	Rp 165,725	Rp 298,375	Rp 365,750	Rp 576,275	Rp 808,413	Rp 916,213	Rp1,232,000	Rp1,563,625
3			Rp 1,050	Rp 14,438	Rp 84,613	Rp 184,100	Rp 238,000	Rp 413,438	Rp 612,413	Rp 706,738	Rp 987,438	Rp1,285,900
4				Rp 1,400	Rp 36,488	Rp 102,813	Rp 143,238	Rp 283,588	Rp 449,400	Rp 530,250	Rp 775,863	Rp1,041,163
5					Rp 1,750	Rp 34,913	Rp 61,863	Rp 167,125	Rp 299,775	Rp 367,150	Rp 577,675	Rp 809,813
6						Rp 2,100	Rp 15,575	Rp 85,750	Rp 185,238	Rp 239,138	Rp 414,575	Rp 613,550
7							Rp 2,450	Rp 37,538	Rp 103,863	Rp 144,288	Rp 284,638	Rp 450,450
8								Rp 2,800	Rp 35,963	Rp 62,913	Rp 168,175	Rp 300,825
9									Rp 3,150	Rp 16,625	Rp 86,800	Rp 186,288
10										Rp 3,500	Rp 38,588	Rp 104,913
11											Rp 3,850	Rp 37,013
12												Rp 4,200
Minimum	Rp 350	Rp 700	Rp 1,050	Rp 1,400	Rp 1,750	Rp 2,100	Rp 2,450	Rp 2,800	Rp 3,150	Rp 3,500	Rp 3,850	Rp 4,200

6. Conclusions

Planning and controlling the number of raw materials is used in production to minimize costs without reducing the quality of the products. MRP for raw material procurement in PT. XYZ is highly recommended because it can help raw material procurement to be more effective and efficient, where the inventory is under control with minimum possible cost. Based on the comparison of forecasting error, the best method chosen is cyclic. The amount of safety stock that the company must prepare is also not excessive. In this case, the MRP method with AWW lot-sizing will result in the lowest costs compared to EOQ, POQ, LFL, Silver Meal Algorithm, and LUC. Using the AWW lot-sizing, the order and storage costs of raw materials will be saving Rp1,285,135 with a percentage of 19% compared to the method PT. XYZ usually used.

References

Assauri, S., *Manajemen Produksi dan Operasi*, Edisi 4, Lembaga Penerbit Fakultas Ekonomi Universitas Indonesia, Jakarta, 1993.

Diana, S. K., *Perencanaan dan Pengendalian Produksi*, Graha Ilmu, Yogyakarta, 2013.

Gasperz, V., *Production Planning and Inventory Control Berdasarkan Pendekatan Sistem Terintegrasi MRP II dan JIT Menuju Manufakturing 21*, Gramedia Pustaka Utama, Jakarta, 2004.

Gozali, L., Andres, and Rhio, H., Usulan Penentuan Teknik Lot Sizing Terbaik dengan Minimasi Biaya dalam Perencanaan dan Pengendaluan Kebutuhan Canvas EP 200 Conveyor Belt di PT. XWZ, *Jurnal Kajian Teknologi*, Vol. 9, No. 2, pp. 135-144, 2013.

Gozali, L., Irena, F., Jap, L., and Nasution, S. R., Material Requirement Planning and Inventory Control Application Program of Crispy Retail at PT. Diva Mitra Bogatama with Application Program Based on c# Programming Language. *Proceedings of the International Conference on Industrial Engineering and Operations Management Dubai, UAE*, 2019.

Hansa, A.P.A., Penerapan Metode Period Order Quantity (POQ) pada Aplikasi Pendukung Optimalisasi Persediaan Bahan Baku Kain di UD. Dwidaku Jaya, Skripsi Universitas Jember, Jember, 2015.

Heizer, J., and Render, B., *Manajemen Operasi Buku 1 Edisi 9*, Salemba Empat, Jakarta, 2009.
Herjanto, E., *Sains Manajemen – Analisis Kuantitatif untuk Pengambilan Keputusan*, Grasindo, Jakarta, 2009.
Nasution, A. H., and Yudha, P., *Perencanaan dan Pengendalian Produksi*, Graha Ilmu, Yogyakarta, 2008.
Nisa, A., Manajemen Persediaan Bahan Baku untuk Model Persediaan Deterministik Dinamis dengan Model Heuristik, UIN Sunan Kalijaga, Yogyakarta, 2016.
Tersine, R. J., *Principles of Inventory and Materials Management Fourth Edition*, Prentice Hall, New Jersey, 1994.

Biographies

Natalia Velony Putri is a university student majoring in Industrial Engineering. She goes to Universitas Tarumanagara for her Bachelor's Degree and hopefully will soon graduate next year. She is an enthusiast individual that actively joining various programs provided by the university. She has participated a number of conferences that IEOM had held, as well as national and international student exchange. She has worked as a private tutor, as well as group tutor in a study center. She has completed her internship experience both in manufacturing and marketing field, whereas she joined PT. DianSurya Global to help the Production Planning and Inventory Control Division for 3 months, particularly in the metal fitting production. Apart from that, she also has been working with Tarumanagara Foundation as a Marketing Intern for a year now.

Lina Gozali is a Lecturer in the Industrial Engineering Department of Universitas Tarumangara since 2006 and a freelance lecturer at Universitas Trisakti since 1995. She graduated with her Bachelor's Degree at Universitas Trisakti, Jakarta – Indonesia, then she got her Master's Degree at STIE IBII, Jakarta – Indonesia, and she recently got her Ph.D. at Universiti Teknologi Malaysia, Kuala Lumpur – Malaysia in 2018. Her apprentice college experience was in paper industry at Kertas Bekasi Teguh, shoes industry at PT Jaya Harapan Barutama, and automotive chain drive industry at Federal Superior Chain Manufacturing. She teaches Production System and Supply Chain Management Subjects. She did a research about Indonesian Business Incubator for her Ph.D. She has written almost 70 publications since 2008 in the Industrial Engineering research sector, such as Production Scheduling, Plant Layout, Maintenance, Line Balancing, Supply Chain Management, Production Planning, and Inventory Control. She had worked at PT. Astra Otoparts Tbk before she became a lecturer.