Analysis of Raw Material Planning with Optimal Cost Consideration Using Safety Stocks, Material Requirement Planning, and Lot Sizing Methods at Plastic Jar Company

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Abstract
PT. XYZ is a manufacturing company specializing in creating and producing plastic jars. Usually, a company has to plan the requirement of raw resources, including the quantity and delivery timetable of raw materials to meet the consumer's needs. Henceforth, to determine the consumer's needs, the company must do thorough calculations to find the optimal quantity of required raw materials. In most cases, there's a chance for any company to receive an unexpected request that comes abruptly. As a result, a safety stocks calculation is carried out to prevent the materials from running out. The main problem of PT. XYZ lies in material requirement planning, which is conducted solely using experience estimation. Hence, a new material requirement calculation needs to be performed utilizing Material Requirement Planning (MRP) and Lot Sizing methods to determine the best quantity and proper delivery timetable while considering the most optimal cost of required raw materials. The most optimal method for procurement of raw materials is the method that has the lowest total cost of procurement. According to the result, the best Lot sizing method is the silver Meal method, with a total cost of USD 35.67 which can reduce the total cost of procurement to 50,8%. Thus, MRP is an effective way to reduce the cost of raw material procurement compared to the usual method used in the company.

Keywords:
Forecasting, Safety Stock, Material Requirement Planning (MRP), Lot Sizing

1. Introduction
PT. XYZ is a manufacturing company specializing in creating and producing plastic jars. PT. XYZ needs several materials to produce and assemble the product. PT accommodates production orders. XYZ in two ways: make-to-order and make-to-stock. The availability of materials becomes very important to maintain the flow of production. Thus, the total amount of required raw materials to conduct the output for the coming periods must be calculated with the forecast calculation. Therefore, it's common for PT. XYZ to get uncertain orders from customers abruptly, which can't be prevented. Unfortunately, PT. XYZ does not implement the calculation to determine the required raw

materials. Instead of ordering raw materials based on experience in terms of quantity and order time which causes a mismatch between the needed amount of demand and the number of raw materials ordered.

The mismatch causes an increase in the total cost of procurement because of the large number of materials that must be stored. Therefore, forecast calculation is used to predict the future demand or quantity of production for coming periods, either demand for raw materials or demand for products. Due to prevent sudden demands, a safety stocks calculation must be conducted. Henceforth, lot sizing methods will be applied to determine the required raw materials. Each form of lot-sizing will be applied in Material Requirement Planning and will be compared to determine which method should be applied in the production schedule by considering the lowest total cost of procurement of raw materials.

1.1 Objective

The main objective of this study is to determine the most optimal quantity of materials that should be ordered and schedule the order times with the Material Requirement Planning (MRP) method for optimizing the cost of procurement of raw materials. Moreover, a safety stock implementation is conducted to prevent the uncertain demand, thus enabling the company to meet every demand, even for uncertain requests.

2. Literature Review

2.1 Forecasting

Forecasts are a technique for predicting the future need of material or demand in the future. Forecasts act as a basis for long-term planning and lead to a more effective and efficient schedule. Forecasts are a sort of reactive planning that includes information about how to coordinate demand for products and services with the required resources to meet the demands (Suhardi et al. l, 2019). Forecasting methods consist of:

1. Simple Moving Average

   A simple Moving Average is the simplest way of analyzing data used in data patterns when the movement is unpredictable but nonetheless stable (Widya and Octavia, 2017).

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

   Remarks:

   F_{t+m} : forecasting value for t + m period
   Xi : observation data in t period
   N : the length of a serial

2. Weighted Moving Average

   Weighted Moving Average is frequently used to smooth up irregular fluctuations in a time series and allows the data analyst to see trend-cycle patterns more clearly over time. The Weighted Moving Average is commonly used to produce short-term time series forecasts and can also be used to build a control chart (Perry, 2010).

$$F_t = W_1 A_{t-1} + W_2 A_{t-2} + \cdots + W_n A_{t-n} \quad (2)$$

   Remarks:

   W_1 : weight assign for period t - 1
   W_2 : weight assign for period t - 2
   W_n : weight assign for period t - n
   N : time period

3. Single Exponential Smoothing

   Single Exponential Smoothing is a method used for unstable or flare-up data patterns over time. The Single Exponential Smoothing depends on three parts of the data: the current actual data, the most recent estimate data, and the constant smoothing data (Yudaruddin, 2019).

$$F_{t+1} = a\, X_t + (1 - a)\, F_t \quad (3)$$

   Remarks:

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

4. Double Moving Average

A Double Moving Average is a method for calculating trends and cyclical patterns in data with a linear trend. This method calculates a set of moving averages (MA) before calculating a second set of moving averages (MA). The second average is the result of the previous moving average, and so on. (Yudaruddin, 2019).

$$S'_t = \frac{X_t+X_{t-1}+X_{t-2}+\cdots+X_{t-N+1}}{N} \quad (4)$$

$$S''_t = \frac{S'_t+S'_{t-1}+S'_{t-2}+\cdots+S'_{t-N+1}}{N} \quad (5)$$

$$a_t = S'_t + (S'_t - S''_t) = 2\,S'_t - S''_t \quad (6)$$

$$b_t = \frac{2(S'_t - S''_t)}{(N-1)} \quad (7)$$

$$F_{t+m} = a_t + b_{tm} \quad (8)$$

Remarks:

F_{t+m} : forecasting from t for the next m periods

X_t : forecasting data

5. Linear Regression

Linear regression is a type of regression in which a straight line represents the relationship between variables. Linear regression is used both for time series forecasting and causal relationship forecasting, it is a time series analysis when the dependent variable changes as a result of time, and a causal relationship exists when one variable changes as a result of another variable's change (Jacobs et al, 2011). Linear regression is useful for long-term forecasting of significant occurrences and aggregate planning.

$$Y(t) = a + b(t) \quad (9)$$

$$b = \frac{n\,\Sigma xy - \Sigma x\,\Sigma y}{n\,\Sigma x^2 - (\Sigma x)^2} \quad (10)$$

$$c = \frac{\Sigma y - b\,\Sigma t}{n} \quad (11)$$

Remarks:

Y : the value of the dependent variable

a : intercept

b : slope

X : independent variable

N : the amount of data

6. Quadratic Regression

The quadratic regression method attempts to fit a line to the data that minimizes the sum of the squares of the vertical distance between each data point and the line's corresponding point (Jacobs et al., 2011).

$$Y(t) = a + bt + ct^2 \quad (12)$$

$$b = \frac{y\delta - \theta\alpha}{y\beta - \alpha} \quad (13)$$

$$c = \frac{\theta - b\alpha}{\gamma} \quad (14)$$

$$a = \frac{\Sigma\,Y(t) - b\,\Sigma t - c\,\Sigma t^2}{N} \quad (15)$$

2.2 Safety stock

Safety stock is an additional product that is stored inside the warehouse to avoid out-of-stock situations due to uncertainty in demand. Appropriate safety stock will allow business operations to flow efficiently. Safety stock guarantees when a product is out of stock (Hudori, 2018).

2.3 Lot sizing

Lot sizing calculates the optimal quantity or order size that must be ordered by considering the most optimal aspects of ordering costs and storing materials (Suhardi,2019). Lot sizing is done following the Material Requirement Planning. It is essential to consider the amount of material that will be booked as well as the booking time interval when calculating lot-sizing because these factors will affect the cost expenditure. Lot sizing methods consist of:

a. Economic Order Quantity (EOQ)

Economic Order Quantity is one lot-sizing method that calculates the number of raw materials by considering the holding cost and order cost of the materials.

$$EOQ = \sqrt{\frac{2DS}{H}} \quad (16)$$

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

b. Lot for Lot
Lot for Lot is a method where the quantity of the raw material for each period is determined by the requirement of raw materials of its period. The order frequency is conducted for every period, minimizing holding costs (Dolgui, et al. 2005).

c. Period Order Quantity (POQ)
Period Order Quantity is a method to calculate the quantity of required raw materials for a fixed period of time (Hansa, 2015).

$$EOI = \frac{EOQ}{R} = \sqrt{\frac{2c}{RPH}} \quad (17)$$

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

d. Least Total Cost (LTC)
Least Total Cost is a method of lot-sizing to determine the quantity of required raw materials by comparing the cost of the order and the cost of holding raw materials, which is meant to minimize the total cost of procurement of raw materials (Gozali, et al. 2013).

e. Silver Meal
Silver Meal is a method of lot-sizing to determine the quantity of required raw materials by minimizing the total cost of procurement (Silver, E. A., and Meal, H. C. 1973).

$$\frac{TRC(T)}{T} = \frac{c + Ph\,\Sigma(k-1)Rk}{T} \quad (18)$$

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

f. Least unit Cost (LUC)
Least Unit Cost is one of the lot-sizing methods to determine the quantity of required raw materials by calculating the lowest cost per unit from each period (Gozali, et al. 2013).

$$V(L) = \frac{s + (h\,\sum_{t=T}^{L}[(t-dT)dt]}{J} \quad (19)$$

Remarks:
s : order costs
h : storage costs
t : N period
L : the last period in which a cumulative lot should be included
T : the cumulative lot has been calculated in the first period.
J : each period's total lot

dt : quantity needs in t period

g. Wagner Within Algorithm (AWW)
Wagner Within Algorithm is a lot-sizing method that determines the quantity of required raw materials by trying all possibilities of order combinations for a determined period of time (Rajhans and Kulkarnia. 2013)

2.4 Material Requirement Planning
Material Requirement Planning is a method of planning and controlling the quantity and timing of demand products to meet the requirements of the master production schedule and optimal costs (Kumar and Suresh, 2008). The Material Requirement Planning input required for planning calculation are Master Production Schedule, Bill of Material, Lead time, orders, item master, and Requirements.

2.5 Master Production Schedule
Master Production Schedule is a method of production planning that involves establishing the amount and time of a final product to be ready by the schedule that must be followed. The master production schedule is created by determining a good production and product ordering schedule for consumers based on the forecasted results (Rasjidin et al. l, 2007). Total demand data, production plans, planning data, Rough Cut Capacity Planning information, and inventory status are all required inputs for the Master Production Schedule.

2.6 Bill of Materials
Bill of Materials is a list of all materials, parts, subassemblies, and the amounts needed to make a single unit of product. The Bill of Materials can also be used to calculate the cost of a product (Widya and Octavia, 2017).

3. Methods
There are several methods that have been conducted by the researchers to accomplish the research that can be seen in the flowchart in Figure 1.

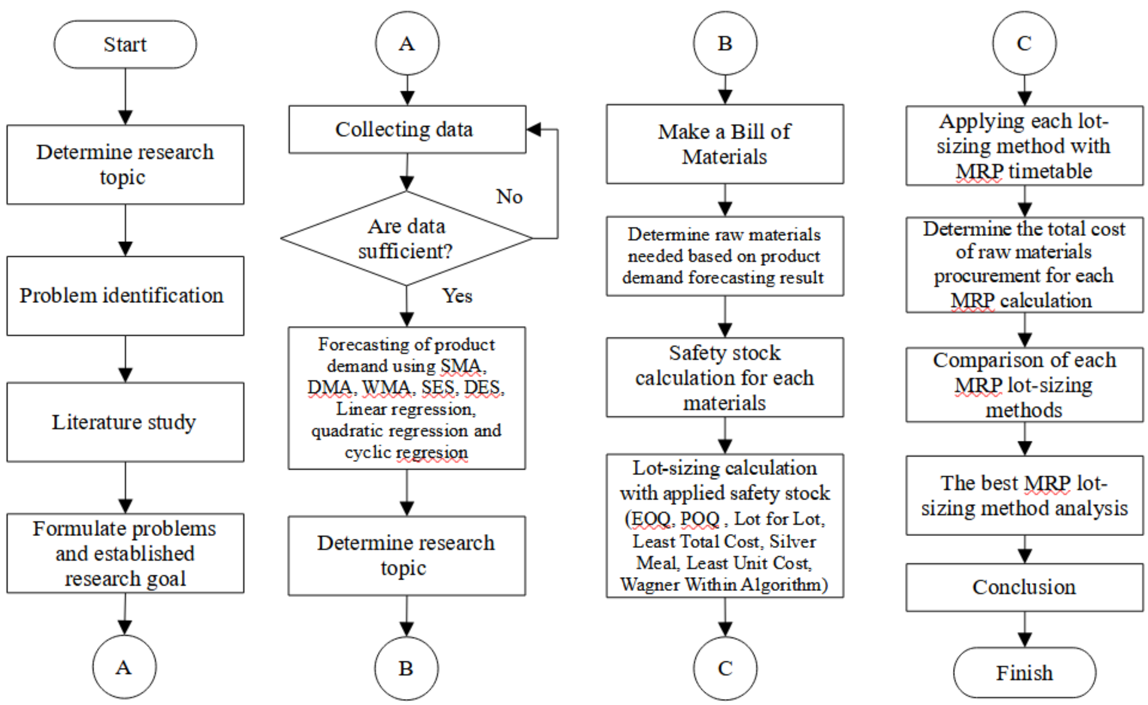

Figure 1. Method Flowchart

4. Data Collection
Several data are needed. Data of product order requests are required to determine the future demand for product order requests and the quantity of required raw materials, which can be seen in Table 1.

Table 1. Product Order Request Data for Fourteen Periods

Period	Month	Quantity of request
1	January 2021	112512
2	February 2021	84156
3	March 2021	72504
4	April 2021	62580
5	Mei 2021	28284
6	June 2021	35088
7	July 2021	12900
8	August 2021	10824
9	September 2021	17856
10	October 2021	29712
11	November 2021	56712
12	December 2021	82392
13	January 2022	106848
14	February 2022	93420

The next activity is finding the lowest total cost of raw materials procurement, delivery and holding costs for each raw material are required, as shown in Table 2.

Table 2. Delivery Cost and Holding Cost for Each Raw Material

General Purpose Polystyrene (GPPS)		
Holding Cost/ ton	USD	0.064
Delivery Cost/ delivery	USD	3.16
Polypropylene (PP)		
Holding Cost/ ton	USD	0.069
Delivery Cost/ delivery	USD	3.36

5. Result and Discussion

5.1 Forecasting

Forecasting determines the future demand of product order requests and the quantity of required raw materials. The forecasting calculation is carried out for the next twelve months using the quadratic regression method because it has the lowest error value of any other method. Forecasting results of product order requests are listed in Table 3 and the graph of forecasting results can be seen in Figure 2.

Table 3. Forecasting Results of Product Order Request Data for Next Twelve Months

Period	Month	Forecasting Result
1	March 2022	66416.87
2	April 2022	48648.23
3	Mei 2022	35323.24
4	June 2022	26441.88
5	July 2022	22004.18
6	August 2022	22010.11
7	September 2022	26459.69
8	October 2022	35352.91
9	November 2022	48689.77
10	December 2022	66470.27
11	January 2023	88694.42
12	February 2023	115362.21

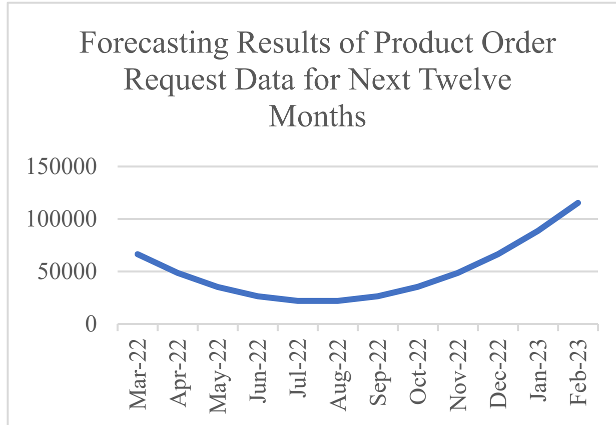

Figure 2. Graph of Forecasting Results of Product Order Request Data for Next Twelve Months

5.2 Bill of Materials

A Bill of Materials is a structure that consists of a list of all materials, components, and the quantity of required raw materials to make a single product unit. The Bill of Materials for the plastic jar can be seen in Figure 3.

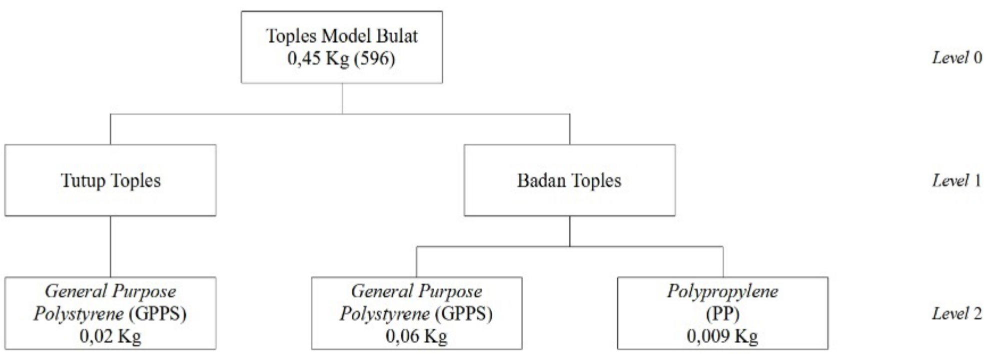

Figure 3. Bill of Materials of Plastic Jar

Based on forecasting results of product order request data and the total amount of required raw materials that are needed to make a single unit of product, the estimation of required raw materials for each material and each period on the following twelve periods can be obtained, which can be seen in Table 4,

Table 4. Estimation of Required Raw Materials for Each Material and Period on the Next Twelve Periods

Period	Month	Required Materials Quantity (Ton)	
		GPPS	PP
1	March 2022	5.31336	0.597753
2	April 2022	3.89192	0.437841
3	Mei 2022	2.82592	0.317916
4	June 2022	2.11536	0.237978
5	July 2022	1.7604	0.198045
6	August 2022	1.76088	0.198099

Period	Month	Required Materials Quantity (Ton)	
		GPPS	PP
7	September 2022	2.1168	0.23814
8	October 2022	2.82824	0.318177
9	November 2022	3.8952	0.43821
10	December 2022	5.31768	0.598239
11	January 2023	7.0956	0.798255
12	February 2023	9.22904	1.038267
Total		**48.1504**	**5.41692**

5.3 Safety Stock

Safety stock is extra stocks stored and preserved to prevent and avoid stock out due to uncertain demand. The safety stock calculation of each material can be seen in Table 5.

Table 5. Safety Stocks Calculation for Each Material

Material(s)	Sf (90%) Z-Tabel	Lead Time (Day)	Lead Time (Month)	Average Demand	Standard Deviation	Safety Stock(s)
GPPS	1.28	11	0.3667	4.01253	2.2414	2
PP	1.28	10	0.3333	0.45141	0.2522	1

5.4 Lot Sizing in Material Requirement Planning (MRP)

Material Requirement Planning (MRP) is a method or technique of planning and controlling the production flow, including the quantity of demand and timing of products to meet the requirements of the master production schedule and optimal cost. MRP's main objective is to provide detail regarding the quantity of required materials and the order schedule of raw materials. Meanwhile, lot sizing is a method to determine the optimal amount by considering the most optimal total cost of procurement. The following methods of lot-sizing are used to discover the most optimal total cost of procurement, including the following:

a. Economic Order Quantity (EOQ)
   Economic Order Quantity calculation is done for each material and applied in the MRP timetable for both materials General Purpose Polystyrene (GPPS) and Polypropylene (PP). Total cost of inventory and order for each material with the EOQ method can be seen in Table 6.

Table 6. Total Cost of Inventory and Order for Each Material with EOQ Method

Materials	Cost of		
	Inventory	Order	Total
GPPS	USD 39.42	USD 6.32	USD 45.73
PP	USD 37.77	USD 3.36	USD 41.43

b. Lot for Lot
   Lot for Lot calculation is done for each material and applied in the MRP timetable for both material General Purpose Polystyrene (GPPS) and Polypropylene (PP). Total cost of inventory and order for each material with the Lot for Lot method can be seen in Table 7.

Table 7. Total Cost of Inventory and Order for Each Material with Lot for Lot Method

Materials	Cost of		
	Inventory	Order	Total
GPPS	USD 4.64	USD 75.82	USD 80.46
PP	USD 1.67	USD 80.66	USD 82.32

c. Period Order Quantity (POQ)
POQ calculation is done for each material and applied in the MRP timetable for both materials General Purpose Polystyrene (GPPS) and Polypropylene (PP). Total cost of inventory and order for each material with the POQ method can be seen in Table 8.

Table 8. Total Cost of Inventory and Order for Each Material with POQ Method

Materials	**Cost of**		
	Inventory	**Order**	**Total**
GPPS	USD 25.83	USD 6.32	USD 32.15
PP	USD 6.79	USD 3.36	USD 10.15

d. Least Total Cost (LTC)
The least Total Cost (LTC) calculation is done for each material and applied in the MRP timetable for both materials General Purpose Polystyrene (GPPS) and Polypropylene (PP). Total cost of inventory and order for each material with the LTC method can be seen in Table 9.

Table 9. Total Cost of Inventory and Order for Each Material with LTC Method

Materials	**Cost of**		
	Inventory	**Order**	**Total**
GPPS	USD 12.53	USD 12.63	USD 25.17
PP	USD 4.69	USD 6.72	USD 11.41

e. Silver Meal
Silver Meal calculation is done for each material and applied in the MRP timetable for both materials General Purpose Polystyrene (GPPS) and Polypropylene (PP). Total cost of inventory and order for each material with the silver Meal method can be seen in Table 10.

Table 10. Total Cost of Inventory and Order for Each Material with Silver Meal Method

Materials	**Cost of**		
	Inventory	**Order**	**Total**
GPPS	USD 12.56	USD 12.64	USD 25.20
PP	USD 3.75	USD 6.72	USD 10.47

f. Least Unit Cost (LUC)
The least Unit Cost (LUC) calculation is done for each material and applied in the MRP timetable for both materials General Purpose Polystyrene (GPPS) and Polypropylene (PP). Total cost of inventory and order for each material with the LUC method can be seen in Table 11.

Table 11. Total Cost of Inventory and Order for Each Material with LUC Method

Materials	**Cost of**		
	Inventory	**Order**	**Total**
GPPS	USD 14.08	USD 12.64	USD 26.71
PP	USD 2.81	USD 13.44	USD 16.25

g. Wagner Within Algorithm (AWW)
Wagner Within Algorithm (AWW) calculation is done for each material and applied in the MRP timetable. MRP timetable for General Purpose Polystyrene (GPPS). Total cost of inventory and order for each material with the AWW method can be seen in Table 12.

Table 12. Total Cost of Inventory and Order for Each Material with AWW Method

Materials	**Cost of**		
	Inventory	**Order**	**Total**
GPPS	USD 10.99	USD 34.75	USD 45.75
PP	USD 6.79	USD 3.36	USD 10.15

5.5 Discussion

In this study, the implementation of MRP is conducted due to optimization of production flow, regarding the number of raw materials, order schedule, and particularly total cost of procurement of raw materials. Safety stock calculation is also being conducted due to uncertainty demand, which is added up by the lot size from the lot-sizing analysis for each method. The lot size from each method is applied in MRP Timetable to find the total cost of procurement of raw materials based on the applied method. The Comparison total cost of procurement of raw materials from each lot sizing method can be seen in Table 13. Then, we can see the cost difference of all lot sizing methods in Figure 4.

Table 13. The Comparison total cost of procurement of raw materials from each lot sizing method

Methods	**Materials**					
	GPPS		**PP**		**Total**	
Total Cost of Procurement Before Lot Sizing Implementation	USD	53.65	USD	18.87	**USD**	**72.51**
EOQ	USD	45.73	USD	41.13	**USD**	**86.86**
Lot For Lot	USD	80.46	USD	82.32	**USD**	**162.78**
POQ	USD	32.15	USD	10.15	**USD**	**42.30**
LTC	USD	25.17	USD	11.41	**USD**	**36.58**
Silver Meal	USD	25.20	USD	10.47	**USD**	**35.66**
LUC	USD	26.71	USD	16.25	**USD**	**42.97**
AWW	USD	45.75	USD	10.15	**USD**	**55.90**

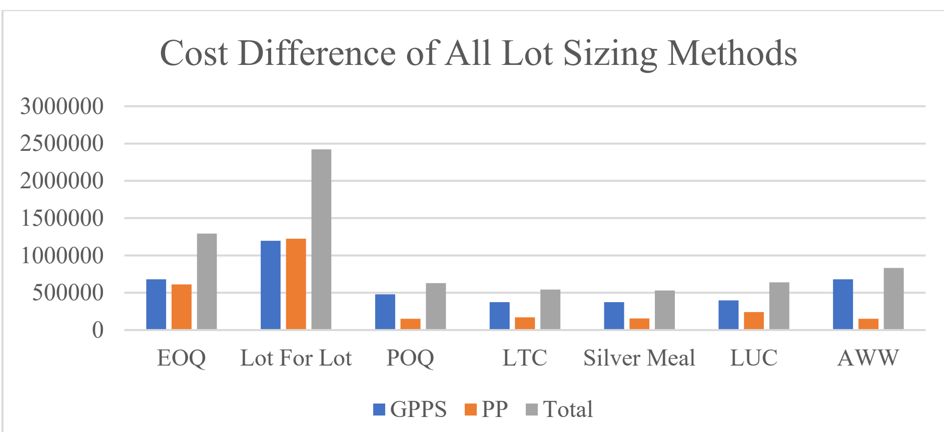

Figure 4. Cost Difference of All Lot Sizing Methods

As a result, the best method of lot sizing is determined by the most optimal cost or in other words, the lowest cost of the method from another method. The Silver Meal method has the most optimal cost of procurement of raw materials with USD 35.67. The Implementation of MRP and Lot sizing calculation can reduce the total cost of procurement by

USD 36.86 or equivalent to 50.8% more efficient than the total cost of procurement before the implementation of MRP.

In order to prove the effectiveness of MRP despite its simplicity, some comparisons from other research are presented in the discussion section. According to the journal "Application of MRP System for Control of Raw Material Inventory with EOQ Lot Sizing" (Christifan and Gozali, 2020), the use of MRP with Lot sizing can be concluded EOQ, in this case, will result in lower costs than not using it. The cost of ordering and holding raw materials if using the EOQ method can be reduced by USD 726.12 or equivalent to 54.18%. On the other side, in the journal titled "Aggregate and Disaggregate Production Planning, Material Requirement, and Capacity Requirement" (Lefta et al., 2020), among the various lot sizing methods that were used, Algorithm Wagner Within (AWW) with the total cost of procurement in USD 155,341.48 of all grades. In the third journal titled "Production Planning and Control Industry 4.0 on Plastic Bottles with the Blow Molding Process (Case Study: PT. Peace Industrial Packaging)" (Chandra et al. 2021), the lot-sizing method that has been chosen for calculating MRP is the silver Meal method with total cost reduction by 8% with a total price of USD 2,891,982.42. In the last journal titled "Material Requirement Planning on Y-Strainer Production (Case study at PT. XYZ)", the best lot sizing method of the research is AWW (Wagner Within Algorithm) which can reduce the total cost by USD 86.40 or equivalent to 19% compared to the usual method that is used in the company (Putri and Gozali, 2021).

From the comparison of the various research conducted, every research that implemented the MRP calculation has a different best method of lot-sizing used. The chosen method is the best method for the company that wants to implement the MRP because the method has the most optimal cost of procurement of raw materials. Each applied approach is proven effective in reducing the total cost of procurement. As a result, MRP with applied lot sizing methods can increase the effectiveness and efficiency of material planning, particularly in terms of the cost of procurement. The results of MRP have shown its flexibility to adapt to the issue scenarios that arise in each company by developing the optimal approach to raw materials procurement according to the problems, mainly by considering the most optimal total cost of procurement of raw materials.

6. Conclusion

From this research, we can conclude that the required quantity of safety stocks is able to be determined where General Purpose Polystyrene (GPPS) is 2 tons of raw materials and Polypropylene (PP) is 1 ton of raw materials. Every lot-sizing method used in this research can determine the optimal quantity based on its method applied in the MRP timetable. As a result, the best lot sizing method is Silver Meal because it has the most optimal cost of procurement of raw materials with USD 35.67. Before the implementation of MRP, the total cost of procurement of raw is USD 72.53. We can conclude that the implementation of MRP, is able to reduce the total cost of procurement of raw materials by USD 36.86 or equivalent to 50.8%. The result has shown MRP's flexibility to adapt to the issue scenarios that happened in the company by developing the optimal approach to raw materials procurement according to the problems. Despite its simplicity, MRP has a significant impact and contributions to a company to improve production flow efficiency. Particularly regarding the total cost of raw material procurement.

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Biography

Dennis Marchello was born in Jakarta, Indonesia, on 10th July 2001. He graduated from Bunda Hati Kudus High School. He is currently studying at Tarumanagara University, majoring in Industrial Engineering. He enjoys reading various genres of books, especially philosophy books in his free time to extend his perspective. He has joined the student representative council organization to develop interpersonal skills. He also shows experience in Production Planning and Inventory Control (PPIC) from the latest internship. He is seeking more opportunities by encountering various challenges to hone his skills.

Jessica was born in Tanjung Balai Karimun, Indonesia, on 7th February 2004. She graduated from Maha Bodhi High School. She is currently studying at Tarumanagara University, majoring in Industrial Engineering. During her free time, she enjoys reading various genres of books in her free time to increase her knowledge. She is also a language enthusiast who enjoys learning English and Mandarin. She is also actively participated in several organizations, particularly the theatre club. Even though she's actively participated in several organizations, she has the encouragement to seek more opportunities to continuously learn and grow her academic experiences and also hone her skills.

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