ANALYSIS OF A01 RAW MATERIAL REQUIREMENT PLANNING USING THE LOT SIZING WAGNER WITHIN, LOT FOR LOT, AND PERIOD ORDER QUANTITY

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Abstract

PT. XYZ is engaged in manufacturing painting which produces various types of decorative paints. One of the products with the highest sales capacity is CK ABC 901; The main raw material in producing this CK ABC 901 is A01 with a total usage of 35.85%. The main raw material greatly affects most of the production process. The problem faced by the company is the absence of resources which control the inventory of raw materials every month. Thus it causes the purchase of raw materials not in accordance with consumer demand and causes problems at the costs that should be minimized. Therefore, the company needs to control the supply of the raw materials so that the production process. One of the methods used in overcoming

company problems is Material Requirements Planning with data processing obtained from ARIMA forecasting results using the Crystal Ball application. Forecasting results are used as input in determining the amount of raw material or lot size which needs to be provided to carry out the production process. This research focuses on lot sizing method of LFL, POQ and Wagner Within to get the minimum total cost of inventory. The results of calculations using the MRP method obtained that the total cost of raw material inventory using the technique of the lotting algorithm of Wagner Within is Rp. 1,967,376. Where the fulfillment of raw materials is carried out 6 times, namely December 2020, February, March, April, June, August and October 2021 with a total order of 4399 Kg, 3697 Kg, 3358 Kg, 3173 Kg, 3836 Kg, and 4242 Kg.

Keywords: ARIMA, Material Requirement Planning, LFL, POQ, Wagner Within.

Introduction

Today the manufacturing industry sector in Indonesia is growing rapidly. This spurs manufacturing companies to deliver quality products and services at affordable prices with timely fulfillment. One of the factors which play a very important role in achieving the goals of an industrial company is the supply of raw materials. Inventory is *stock* or storage of goods that are kept by the company in inventory related to the running business[1]. According to [2] the inventory is a number of materials, *parts* provided and materials provided for the production process, as well as finished goods or products provided to meet requests from components or subscriptions at any time. The main function of the company to have the inventory is so that the company can buy and manufacture the products in small number of quantity[3, 4].

A01 is the raw material for CK ABC 901 product which most widely used namely 35.85%, the demand for CK ABC 901 products is fixed, but the every month demand is varied. The number of requests fluctuative but the amount has been set by the consumer for the next several periods, therefore a dynamic deterministic inventory control model can be used (Fatma, 2019). In line with it, this study uses a dynamic deterministic inventory approach.

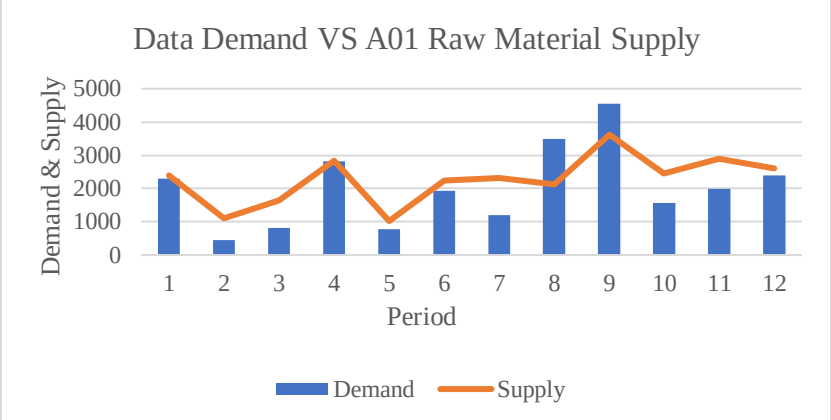

Figure 1. Data *Demand vs* A01 Raw Material *Supply* in 2020

Figure 1 shows comparative data between *demand* and *supply* of raw materials for A01 in 2020, there was a shortage of raw materials in August and September. This is a problem faced by the company because there are no resources which control the inventory of raw materials every month. Therefore, the company must have the right strategy to plan the inventory of raw materials so that the company can fulfill an effective and efficient production plan.

In order to overcome the problems faced by companies today, the method that can be used is MRP (*Material Requirement Planning*), because this method has benefits which can be used for planning and controlling items (components) that

depend on items at a higher level [5]. MRP is a method for determining what, when, and how much raw material is required to meet the needs of a production plan[5]. According to[6] MRP can help companies to schedule and to plan the purchasing of raw materials to the suppliers, and it is expected that companies will carry out inventory management effeciently. The MRP system is a planning and scheduling system for raw material requirements, MRP can overcome complex problems which arise in inventory, MRP is more complex to use but can provide several advantages such as lower inventory levels, accuracy of production schedules and direct financial impact on company because MRP decrease the costs [7]. MRP method can be used to calculate the need of raw materials for production; this system can calculate the amount of raw material needed to complete a product in the future so that companies can optimize the availability of raw materials needed so that the amount of inventory is precise[8].

The purpose of this research is to determine the schedule for ordering raw materials A01 which produces the lowest cost in total. The technique lot sizing used is LFL (Lot for Lot), Period order quantity (POQ), and the algorithm Wagner Within (AWW). The selection of this method is also based on several journals including research conducted by[9] which compares the EOQ and POQ methods to minimize the cost of perfume packaging materials. The results show that the POQ method is more effective in reducing the costs by up to 30% on bottled packaging materials compared to the EOQ method. In line with it, [10] discovers a comparison between the *LFL, FOQ,* Fixed and Period Requirement (FPR) to minimize the cost of raw mix concrete materials methods, it is proven that the LFL method produces the lowest cost with a comparison of each method of 33.2: 33, 4: 33.4. [11] using the EOQ and AWW methods to streamline the number of each main product stored in the warehouse. The results show that the most efficient main product stored was using the AWW method with a total cost percentage of 16.7% smaller than the *EOQ* method[12].

Literature Review

The Pareto Diagram

The use of the diagram in this study is to identify or select the main problems in making raw material inventory policies. Pareto charts are used to compare various categories of events arranged according to size, from the largest on the left to the smallest on the right. This arrangement will help us to determine the importance or priority of the categories of events or causes of events being studied or to identify the main problems in the process. By using Pareto diagrams, activities will be more effective by focusing on the causes that have the greatest impact to the events rather than reviewing various causes at one time[9, 13, 14]

Forecasting

Forecasting is a very important element in the decision-making process, forecasting is also the estimation of sales at a time in the future under certain circumstances and it is made based on data which has occurred and/or may occur. The result of the forecast is an assessment of future conditions regarding sales as a technical projection of potential consumer demand[15]. The data used for the 2021 forecasting process for the CK ABC 901 product is the data of January 2018 – December 2020 (36 months), the data is then processed using Autoregressive Integrated Moving Average (ARIMA) method. The use of the ARIMA method in short-term forecasting is very appropriate because the ARIMA method has a high accuracy. And also determine a good statistical relationship between the variables to be predicted with the value used for forecasting. As for long-term forecasting, the accuracy of the forecast is not good. Usually the forecast value will tend to be constant for a fairly long period[7, 16, 17].

According to[18], one type of software that can support forecasting calculations easily and quickly is CB Predictor. CB Predictor is a program that is in Crystal Ball. This program is a program to predict data that will occur in the future by analyzing the previous data. In this program gallery, eight forecasting models are available, namely: (a) Single Moving Average, is a forecasting method used for stationary data (does not contain seasonal or trend elements); (b) Double Moving Average, is a forecasting method used for data which contains trend elements; (c) Single Exponential Smoothing, is a forecasting method used for stationary data (does not contain seasonal or trend elements); (d) Double Exponential Smoothing, is a forecasting method used for data which contains trend elements; (e) Seasonal Additive, is a forecasting method used for data with seasonal elements; (f) Holt Winter's Additive, is a forecasting method used for data which contains seasonal and trend elements; (g) Seasonal Multiplicative, is a forecasting method used for seasonal data. This method is the best method for data with the highest aggregation, such as product sales and data on raw material needs.

Material Requirement Planning (MRP)

MRP is used to determine the amount and time in ordering A01 raw materials by using demand data from forecasting results for 2021. MRP is one of the method used to control raw materials. MRP is an information system that is used to plan the raw material required in supporting the manufacturing program which has been determined[18]. The MRP system allows companies to reduce inventory levels, make better use of labor and facilities, and improve customer service [19] in [7]. According to [18] The implementation of an MRP has a process consisting of four main steps, namely compiling the BOM (Bill of Materials), calculating the net raw material requirements (net requirements), conducting lot sizing, and compiling time phasing requirements.

Lot For Lot (LFL) Method

According to [19-21] LFL is a method to determines the lot size which is carried out on the basis of the same order or adjusted to the number of needs in the calculated period as a step to minimize storage costs[22].

Method of Period Order Quantity (POQ)

According to[20] POQ is an approach using the concept of economic order quantity so that it can be used in discrete or various demand periods. The calculation of the POQ method uses the following formula (Heizer & Render, 2011):

$$EOQ = \sqrt{\frac{2DS}{H}} \quad (1)$$

$$POQ = \frac{EOQ}{R} \quad (2)$$

Remarks:
EOQ = Optimal inventory quantity
R = Average usage per period
D = Production rate per year
S = Order cost per order
H = Storage cost per kg per year

The Wagner-Within Algorithm (AWW)

AWW method is a method that uses a dynamic programming approach which will later get an optimal solution[23]. The purpose of this technique is to obtain an optimal ordering strategy for the entire net demand schedule by minimizing the total procurement and holding costs, the AWW steps are as follows:

Step 1

Calculate the total cost matrix (order cost and holding cost), then define O_{en}. The formula for O_{en} is stated as follows:

$$Oen = A + h \sum_{t=e}^{n}(qen - qet)$$

As for $1 \leq e \leq n \leq N$

Where:

A : Order fee (Rp/order)

h : cost per unit per period (Rp/unit/period)

qet: $\sum_{t=e}^{n} = Dt$

Dt : Demand in *t* period

e : The initial limit of the period covered by the *qet* order

n : Maximum period covered by *qet* order

Step 2

The value *fn* is the value of total costs and optimal order which is calculated using the following formula:

$$\boldsymbol{f_n = Min\ [O_{en} + f_{e-1}]}$$

As for *e* = 1, 2,., *n* dan *n* = 1, 2,., *N*

Step 3

The optimal solution fT obtained from the recursive backwards calculation as follows:

a. $f_N = O_{en} + f_{e-1}$

The last-order is made in period *e* to fulfill demand from period e to period *N*

b. $f_e\text{-}1 = O_{ve-1} + f_{v-1}$

The order before the last-order must be made in period *v* to meet the demand from period *v* to period *e-1*

c. $f_u\text{-}1 = Ou_{-1} + f_0$

The first order must be placed in period 1 to fulfill demand from period 1 to period *u-1*.

Research methods

There are two steps in collecting the data at PT XYZ. First is the direct observation to the field and conducting interviews in one of the company's departments to collect the necessary information and data. Second is the company archives as information that supports data processing in this study. The stages of this research are shown in Figure 2.

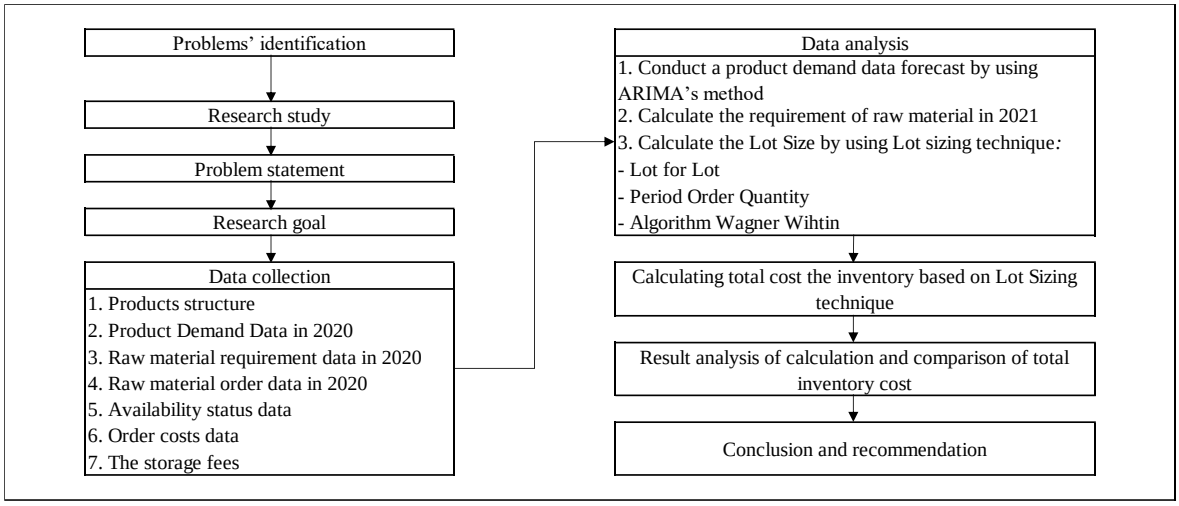

Figure 2. Stages of Research

Result and Discussion

Selecttion of Research Objects

PT XYZ is one of the manufacturing companies engaged in the manufacture of paints. PT XYZ is committed to "innovation, quality and service are the keys." The company always strives to provide high quality products and satisfactory service. PT. XYZ produces various kinds of paints, but in this study the products selected were based on the best-selling products with the criteria of the largest number of sales obtained by the company as shown in Table 1.

Table 1

Best selling products at PT. XYZ 2020

Product	Number of Requests (kg)	Price/kg	Total Price
CK ABC 901	70915	Rp.49.500	Rp3.510.292.500
CK ABC 902	48697	Rp.52.000	Rp2.532.244.000
CK ABC 990	32274	Rp.52.500	Rp1.694.385.000

Based on Table 1, CK ABC 901 hits the highest sales. Furthermore, the structure of the CK ABC 901 product is made to determine the raw materials that will be the object of research.

Table 2

Regression Results of Model (Dependent= Customer Satisfaction)

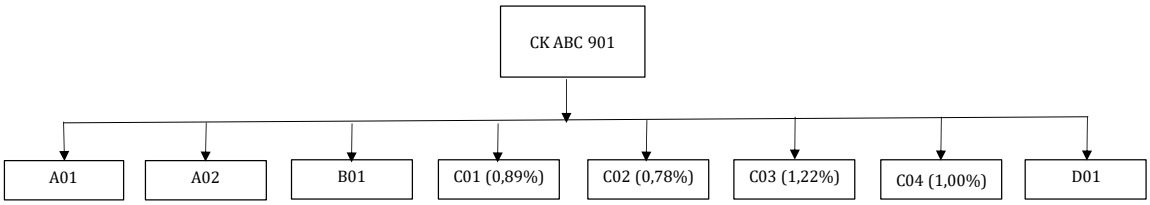

Figure 3. Product Structure ABC 901

Figure 3 shows the ingredients for the CK ABC 901 paint product. The most widely used raw material for the manufacture of CK ABC 901 products is A01 raw material at the number of 35.89% of the total raw materials for CK ABC 901. To show the main priority of raw materials needed in making CK ABC 901, a Pareto diagram is used.

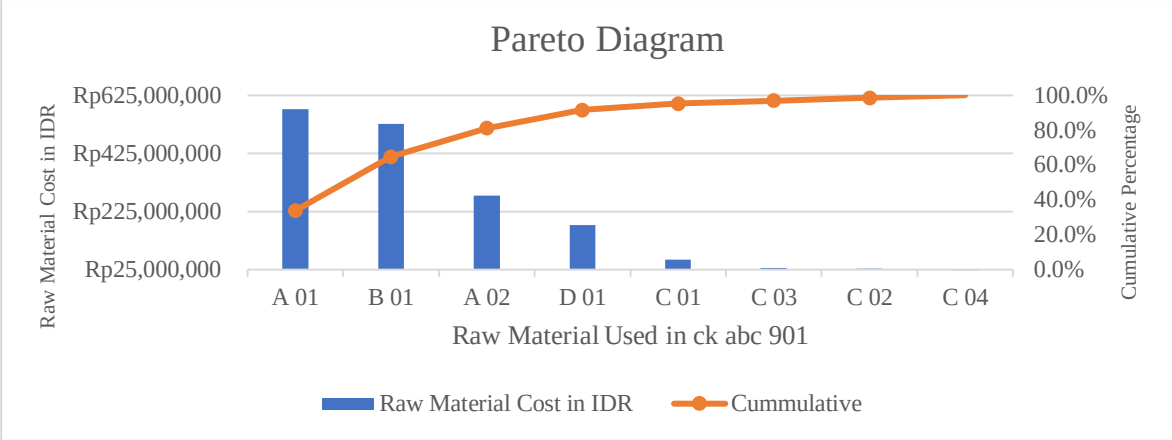

Figure 4. Pareto Diagram of Raw Material Needs for CK ABC 901

Based on Figure 4. There are 8 raw materials needed, it is known that A01 is the main raw material needed in the production of CK ABC 901, with a total cost of purchasing raw material of Rp. 578. 475,779 and the percentage of raw material needed is 35.85%. This is used as a basic reference in determining the need for ordering raw materials for related products.

Data Processing

After collecting the data, the next step is data processing. This study employs forecasting method and uses the smallest MSE (Mean Squared Error) in processing the data. The results of Forecasting are listed in table 2 and table 3.

Table 2

Forecasting Results for 2021

Month	Sales 2020 (Kg)	Forecast 2020 (Kg)	Raw Material Needed A01 (Kg)
January	7136	7565	2441
February	1404	6728	2171
March	2517	5844	1886
April	8701	5612	1811
May	2398	5476	1767
June	5981	4929	1591
July	3710	4646	1500
August	6571	5185	1673
Septem	9809	5859	1891
October	4862	6027	1945
Novem	6157	6225	2009
Decemb	7394	6919	2233

Table 2 shows the raw material requirements of A01 in 2021 based on the results of forecasting in 2021. The costs of orders and storage of A01 raw materials will be shown in Table 3.

Table 3

Cost of internet

Remarks	Price/Order (IDR)	Total Cost/Order (IDR)
Telephone and Internet fees	Rp 12.000	Rp 12.000
Inspection fees	Rp 175.000	Rp 175.000
Total Costs Order		Rp 187.000

Based on the information obtained, it is found that the cost of ordering A01 raw material is Rp. 187,000/order, it is included the cost of internet calls and the cost of inspection of raw materials.

Table 4

Storage Fee of A01 Raw Material

Storing A01 fee	Total Fee/Kg/Thn (IDR)
Werehouse electricity	Rp24
Man Power fee	Rp50
Total raw data storing	Rp74

The cost of storage is the cost incurred by the company to store raw materials in the warehouse for one year, the cost of storing raw materials for A01 is Rp. 74 per kg per year.

Material Requirement Planning (MRP)

In planning and controlling raw material inventory, the author uses the *Material Requirement Planning* (MRP) method. *Lot Size* used is *Lot for Lot* (LFL), *Period Order Quantity* (POQ) and *Algorithm Wagner Within* (AWW).

Table 5

. **Raw Material Inventory Policy A01Method *LFL***

Lot Size	LFL	2020	2021											
Lead time	**1 Month**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	May	**Jun**	Jul	**Aug**	Sept	**Oct**	**Nov**	**Dec**
Gross Requirement (GR)			2441	2171	1886	1811	1767	1591	1500	1673	1891	1945	2009	2233
Schedule Receipts (SR)														
On-Hand Inventory (OH)	213		0	0	0	0	0	0	0	0	0	0	0	0
Net Requirements (NR)			2228	2171	1886	1811	1767	1591	1500	1673	1891	1945	2009	2233
Planned Order Receipts (PORc)			2228	2171	1886	1811	1767	1591	1500	1673	1891	1945	2009	2233
Planned Order Releases (PORl)	2228		2171	1886	1811	1767	1591	1500	1673	1891	1945	2009	2233	

Based on table 5, it can be seen that the total inventory costs incurred using the LFL method are as follows:

Table 6

A01 Raw Material Inventory Policy based on POQ Method

Lot Size	POQ	2020	2021											
Lead time	1 Month	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	**Aug**	**Sept**	Oct	Nov	**Dec**
Gross Requirement (GR)			2441	2171	1886	1811	1767	1591	1500	1673	1891	1945	2009	2233
Schedule Receipts (SR)														
On-Hand Inventory (OH)	213	9226	7055	5169	3358	1591	0	9751	8078	6187	4242	2233	0	
Net Requirements (NR)			2228	2171	1886	1811	1767	1591	1500	1673	1891	1945	2009	2233
Planned Order Receipts (PORc)		11667	-	-	-	-	-	11251	-	-	-	-	-	
Planned Order Releases (PORl)	11667	-	-	-	-	-	11251	-	-	-	-	-	-	

Based on table 6, the order frequency policy is obtained from the following calculation:

$$EOQ = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2 * 22918 * \text{Rp.}187.000}{\text{Rp.}74}}$$

$$EOQ = 10762.3794$$

$$POQ = \frac{EOQ}{P} = \frac{10763.3794}{1910}$$

$$POQ = 5.634$$

Based on the above calculations, the frequency of ordering A01 raw materials is 1 order to meet demand for 6 months. Thus it can be seen the total inventory costs incurred using the POQ method, are as follows:

Table 7

Lot Size	POQ	2020	2021											
Lead time	1 Month	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Gross Requirement (GR)			2441	2171	1886	1811	1767	1591	1500	1673	1891	1945	2009	2233
Schedule Receipts (SR)														
On-Hand Inventory (OH)		213	2171	0	1811	0	1591	0	1645	0	1945	0	2233	0
Net Requirements (NR)			2228	2171	1886	1811	1767	1591	1500	1673	1891	1945	2009	2233
Planned Order Receipts (PORc)			4399		3697	-	3358-	-	3173	-	3836	-	4242	-
Planned Order Releases (PORl)		4399	-	-	-	-	3358		3836	-	-	4242	-	-

Based on table 7, it can be seen that the total annual inventory cost using the *Wagner Within* method are as follows:

The results obtained using the *Lot for Lot* method, the POQ method and the Wagner Within method, can be compared as follows:

Table 8

Comparison ofTotal Costs of A01 Raw Material by using LFL, POQ and Wagner Within

Method	Order Frequency	Order Fee	Storing Fee	Total Cost
LFL	12	Rp 2.244.000	-	Rp 2.244.000
POQ	2	Rp 374.000	Rp 4.209.860	Rp 4.583.860
Wagner Within	6	Rp 1.122.000	Rp 845.376	Rp 1.967.376

In table 8 it can be seen that the planning and control of A01 raw materials using the Wagner Within method, produces a minimum cost of Rp. 1,967,376. This may happen due to the order lot size of the Wagner Within method is based on an algorithmic calculation of order cost and storing costs which produce a minimum total cost. The order lot size of the *POQ* method is done by determining the number of demand periods that must be fulfilled for each order, while the lot size order of *LFL* method is based on the net need for a period. The frequency of different orders will also affect the number of items stored, thus, it will affect the order costs and storing costs, which will have an impact on the total inventory costs that must be borne by the company.

In this case, although the frequency of ordering *POQ* is less than the frequency of ordering Wagner Within*, the* inventory stored is much more, this causes the total inventory cost of *POQ* method might get bigger number than Wagner Within method.

Conclusion

Based on the results of research that has been carried out, the number of orders for A01 raw materials in 2021 using the MRP method *lot size Wagner Within* is as follows:

Table 9

A01 Raw Materials Order Data in 2021

Order Month	Order amount (kg)
December	4399
February	3697
April	3358
June	3173
August	3836
October	4242

Based on table 9, in according to fulfill the A01 raw material requirement, the order should be proceed 6 times, namely December 2020, February, April, June, August and October 2021. The total cost of inventories in 2021 produced for planning A01's raw material needs is Rp. 1,967,376.

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