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Case Study

Analysis of Inventory Control by Using Economic Order Quantity Model – A Case Study in PT Semen Padang

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A B S T R A C T

Inventory control is a very important issue. It is because the amount of inventory will determine or affect the smoothness of the production process as well as the effectiveness and efficiency of the company. PT Semen Padang is a manufacturing company that produces 10,400,000 tons of cement per year. The achievement of the cement production target at this company depends on the availability of raw materials needed in the cement production process itself. Gypsum is an additional material of the cement production process which is very important because it is a raw material that must exist in the process of making cement. So, if the inventory of gypsum cannot meet the needs of production, then the production process of cement making will be disrupted. PT Semen Padang is using the Min-Max method for the inventory control. But the costs are quite high. The cost of inventory can be minimized by using another method such as EOQ (Economic Order Quantity). The conclusions of this research are in 2016 by using EOQ method, the optimal order quantity is 32,073 ton per order, and the frequency is 9 times in a year with total cost Rp. 4,757,673,813.48, and in 2017, the optimal order quantity is 34,856 tons per order and the frequency is 9 times in a year with total cost Rp. 9,694,805,608.36.

INTRODUCTION

Inventory control is a very important issue [1–3]. The amount of inventory will determine or affect the smoothness of the production process as well as the effectiveness and efficiency of the company [4]. Delays or out of inventory will not only influence the production process but also cause a loss of opportunity to increase profits from a company. The amount or level of inventory required by a company is different for each company, depending on the quantity of production, the capacity of the plant and the production process [5,6].

PT Semen Padang is a manufacturing company that produces cement. The company can produce 10,400,000 tons of cement per year. The achievement of the cement production target at this company depends on the availability of raw materials needed in the cement production process itself. The raw materials for making cement are limestone, silica, clay, iron sand or copper slag, gypsum and pozzolans. Limestone and silica are raw materials that produced in the company, while other raw materials are bought from the suppliers.

Gypsum is one of the raw materials that is bought from the suppliers that located in Cilacap, Central Java. The purpose of adding gypsum is to slow the cement hardening process. Gypsum is an additional material that is very important because without this material the cement production process cannot be done. So, if the inventory of gypsum does not meet the needs of production, then the production process of cement will be disrupted. The demand for gypsum in PT Semen Padang is presented in Figure 1.

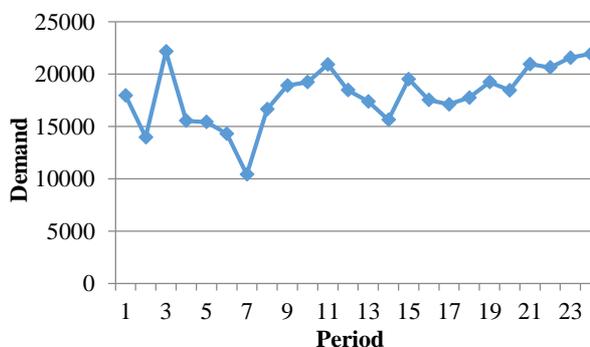


Figure 1. Demand of Gypsum in PT Semen Padang

As is shown on Figure 1, the used of gypsum in PT Semen Padang is fluctuate and keep increasing in period 22nd. The availability

of gypsum determines the cement production process at PT Semen Padang. Therefore, it is necessary to control the inventory of gypsum so the production process will be run smoothly.

PT Semen Padang is already using a method for their inventory control that is the Min-Max method. This method is used to determine the minimum and maximum stock. The used of determining the minimum stock is to avoid a shortage of raw material, and for the maximum stock is to avoid waste of storage cost. But by using this method, the costs incurred by the company can be quite high. The cost of inventory can be minimized by using another method such as EOQ (Economic Order Quantity) [7–10]. In this report, there will be a calculation to get the total inventory cost by using EOQ and compare it with the inventory cost which has been applied by the company. So, the company will be able to minimize the inventory cost.

Based on the background described above, the problem formulation that to be discussed is how to control the inventory of raw material gypsum for the next period and whether the cost of inventory that has been set by the company is already optimal. The objective of this research is to determine the optimal inventory cost for raw material gypsum by using EOQ.

The scope of the research that conducted in PT Semen Padang are as follows:

1. Inventory control is done for raw material gypsum
2. Forecasting is based on the historical data of gypsum demand in 2014 and 2015 for the next two years.

LITERATURE REVIEW

Forecasting

Forecasting is an activity or business that is used to predict the future state through state testing in the past while forecasting demand is the level of demand for the products that are expected to be realized for a certain period in the future [11,12]. Forecasting process will get the results used by management forecasting production or operation in making decisions regarding the selection process, capacity planning, and layout of the facility, and also for decisions that are constantly about planning, scheduling, and inventory. Demand forecasting is useful to know the pattern of customer trends and information about the product

The purpose of forecasting in operational management is to reduce uncertainty in production, so that proactive measures/anticipatory can be done, and for purposes of production scheduling. Forecasting can be affected by the external environment and internal environment. The external environment can be either income customer, promotion of competitors, competitors' prices, availability of products, competitive effectiveness and efficiency of channels used, the characteristics of customers, and so on while the internal environment is the policies carried out within the company, such as promotion policies, costs, and channels.

Forecasting Methods

There are two kinds of forecasting methods, as follows:

1. Qualitative Forecasting Methods

Forecasting that combines an intuitive, emotional, personal experience, and value systems decision-makers to predict. This method is usually used when there is no or little of available past data. Qualitative methods are widely known it is the Delphi method and the nominal method (nominal group technique).

2. Quantitative Forecasting Methods

Using a varied mathematical model with past data and causal variables to forecast demand. Quantitative methods consist of: Methods of Time series ("Hands-free"/graphics, moving average, weight moving average, exponential smoothing, simple linear regression, interpolation Gregory-Newton, winter, ARIMA), and Methods "Non-time Series" (Structural Models).

Quantitative forecasting can be applied when there are three of the following conditions:

1. Available of information about the previous period.
2. Such information can be quantified in the form of numerical data.
3. It can be assumed that some aspects of the pattern of the past will continue in the future.

a. Exponential methods

This method did weighting method decreases exponentially toward the value of a variable or observation ago. Each observation data has contributed to determining the value of forecasting the previous period. However, the calculation is fairly represented by observational data and the results of forecasting in the last period.

b. Quadratic method

The quadratic method is a non-linear trend, and if it drawn shaped like curve lines. This method is usually used or applied to historical data which, if drawn will form lines are not straight or parabolic.

c. Trend cyclical method

Definition of Inventory

Inventory is materials, supplied parts and materials in the process contained in the company's production process, also finished goods or products supplied to fulfill the demand of customers at any time. So, it can be concluded that inventory is the availability of any stock or resources used in an organization that is stored for use in the future period to meet certain objectives.

An inventory control that is run by a company certainly has certain goals, as follows:

1. To fulfill the needs or the demands of the customer faster (to satisfy the customer).
2. To maintain the continuity of production or keep the company did not get the stock-outs that can affect to the problem of the production process such as the stopping of the production process, this is because of the reasons:
 - a. The possibility of goods (raw and supporting materials) become scarce, so it is difficult to obtain.
 - b. The possible of suppliers that can be late to send the goods ordered.
3. To maintain and if possible to increase the company's sales and profits.

4. To keeping small purchases can be avoided that can increase the ordering cost higher.

Function of Inventory

Inventory exists because supply and demand are difficult to synchronize perfectly. Inventory enables a company to support the customer's services, logistics or manufacturing activities in a situation where purchasing or manufacturing of the items is not able to satisfy the demand [13]–[16]. Not only in manufacturing sectors, inventory problem can be found in services area like hospital [17]. Customer desire has always been a vital issue in a company not only to maintain sales but also to increase it. One of the functions of inventory is the anticipate the fluctuate demand so the company can optimize the ability to fulfill the customer demand to increase the company's performance. Inventory has several functions to create stability in the company's operations activity and hide the operational problem.

Types of Inventory

The types of inventory in the company can be categorized in several ways. Based on the function, inventory can be divided into:

1. Batch Stock or Lot Size Inventory, is the inventory that appears where the goods purchased, goods made or transported in large quantities, so the goods gained more and faster than the used or expenditure, and for a while can create an inventory. The profits can earn with the Batch Stock or Lot Size Inventory include:
 - a. Getting a discount on the purchase price.
 - b. The efficiency of production
 - c. There is saving cost for the handling cost.
2. Fluctuation Stock is inventory that use to face the fluctuations of customer demand that cannot be predicted. In this case, the company will make preparations to be able to fulfill customer demand, if the level of demand shows irregular or not fixed and fluctuations in demand cannot be predicted before. So if there are a very large demand fluctuation, then this inventory (fluctuation stock) takes a very big too to keep the possibility of the rise and fall of demand.
3. Anticipation Stock is the inventory which supplies are held to face the unpredictable fluctuations, based on seasonal patterns contained within one year and to deal with the use or sale of the increased demand. Anticipation Stock is also intended to keep the possibility of difficulty obtainable materials, so it's not to interrupt the production process or can avoid the delay of production.

The inventory also can be grouped based on types and position of the item in the sequence of the work product that follows:

1. Inventories of raw materials are the inventory of tangible goods used in the production process, where goods can be obtained from the natural source or purchased from suppliers or companies that produce raw materials for the company. The raw materials in factories use to process become finish goods through of some process.

2. Inventories of parts of products purchased (Purchased parts/components stock), is the inventory of goods which consist of parts received from other companies, which can be assembling directly with other parts without going through the production process before.
3. Inventories of auxiliaries' materials or the supporting goods are the inventory of materials which required in the production process to help the success of the production or used in the operation of a company, but not a part or component of the finished goods.
4. Inventories of finished goods in the process (work in process/progress stock), is the inventory of goods coming out of every part in a single plant or materials which have been processed into a form but needs more to be reprocessed for process becoming the into finished goods. But maybe semi-finished goods for a factory is a finished good for other factories because the production process ends there. May also semi-finished goods that are the raw material for other companies who will process it into finished goods.
5. Finished goods inventory is the inventory of goods that have been fully processed or processed in the factory and ready for sale to customers or other companies. So this is a finished product and has been prepared for sale.

The Function of Inventory

Inventory has several functions to create stability in the company's operations activity. The functions of inventory are as follows:

1. Decoupling function.
The important function of inventory allows the operations of internal and external companies have freedom. This decouples inventories allows the company to fulfill the customer demand without depending on the supplier.
2. Economic Lot Sizing function
Economic Lot Sizing function is a function that enables the company to produce and purchase the number of resources that can reduce the costs per unit. Lot Size function is necessary to consider cost savings. The savings from the discount of purchasing, transportation costs, and so on. These savings costs occur because the company bought in larger quantities.
3. Anticipation function
Anticipation function as the inventory to anticipate the demand that can be forecast and keep the possibility of difficulties in obtaining the raw materials. This function to cope with the uncertainty of the delivery time and the receipt of raw materials during the period of re-ordering. This function is very important to maintain of smoothing production process

The Inventory Costs

Inventory costs are all the expenses and losses caused by the inventory activities. Cost of inventory is generally divided into four types:

1. Purchasing Cost

The purchasing cost is the expenses cost that used to the purchase of goods with a certain number depending on the number of items purchased and the price per unit of goods. The purchasing cost becomes very important when the price of goods is influenced by the size of the purchasing with the price discount is existing where the price per unit will decrease if the number of purchases increased, and also the opposite.

2. Procurement Cost

The procurement costs are the costs related to the purchasing of goods that consist of ordering cost if the goods necessary come from outside the company. Ordering cost is all expenses caused by the activities bring in goods from outside, such as the cost determining of the supplier, typing orders cost, shipping cost, the transportation cost, inspection cost, packing cost, telephone charges, and other costs. Ordering cost is assumed constant for each time of reservation.

$$Ordering\ Cost = \frac{D}{Q}x(A) \tag{1}$$

3. Carrying Cost/Holding Cost

The holding cost is all the expenses caused by the activities of saving goods in a certain period.

$$Holding\ Cost = \frac{Q}{2}x(hxC) \tag{2}$$

4. Stock out Cost/Shortage Cost

The stockout cost reflected the economic consequences caused by stock out of inventory. This could be disadvantages for the company because it would make the company's production process become slow down and the company of the opportunity to make a profit or a customer can move to another company because the demand is not fulfilled. This can make affected to the company's image in the customer perception. As for that including the cost of a stockout is the number of items that are not fulfilled, the fulfillment time and procurement costs of emergencies.

The Inventory Control

Inventory control is an activity to determine the level and composition of assembly (parts) inventory component, raw materials and finish good/products so that the company can protect the smoothing production process and sales also the learning needs of companies with effective and efficient [18]. Inventory control activities are not limited to the determination on the level and composition of inventory, but also including the regulation and supervision or the procurement of the necessary ingredients according to the amount and time required.

If the raw material inventories are low or empty it will lead to delays in the production process and even result in the stopping of the production process, but conversely, if too much inventory will also lead to waste. The purpose of control is expressed as an effort to [18]:

1. Keeping the company to not to run out of inventory that can make stopping of the production process.
2. Keeping the formation of inventories by companies is not too great or excessive, so the costs for inventory of raw materials is not too high.

3. Keeping small purchases can be avoided because this would make the ordering cost higher.

The importance of inventory control about the production process is to ensure a smoothing production process, and the continuity of the plant do not let the company stock out of inventory so that the production process can continue smoothly.

Economic Order Quantity (EOQ)

The model of economic order quantity (EOQ) is a mathematical model to determine the number of items needs to be ordered to fulfill projected demand with the cost of inventory is minimized. EOQ aims to determine the reorder point for independent demand, which the demand for a component that does not depend on the other components of demand. The model used in calculating the EOQ is:

$$EOQ = Q^* = \sqrt{\frac{2AD}{h}} \tag{3}$$

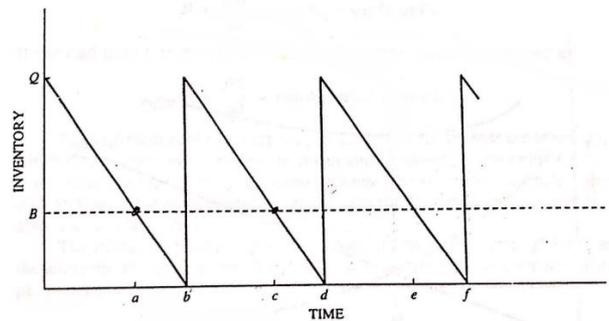


Figure 2. Classical Inventory Model

Figure 3 shows economic order quantity graph. It consists of holding costs, total cost, and ordering costs.

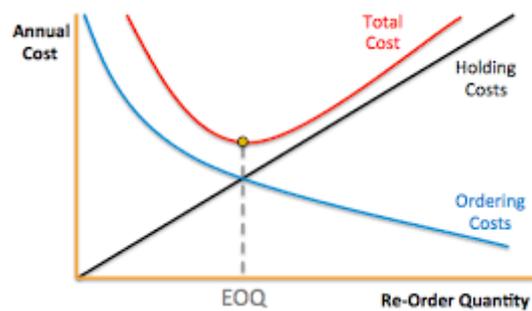


Figure 3. Economic Order Quantity Graph

The total cost of inventory with reservations on EOQ:

$$\begin{aligned} \text{Total Cost} &= \text{Ordering Cost} + \text{Holding Cost} \\ &= \text{The cost each time order} \times \text{order frequency} + \\ &\quad \text{holding cost/unit/period} \times \text{number of average} \\ &\quad \text{inventory} \\ &= (AxF) + (hxm) \\ &= \frac{AD}{Q} + \frac{hQ}{2} \end{aligned} \tag{4}$$

Assumptions to apply the EOQ model are:

1. The demand for the product is constant, uniform and outermost (Deterministic).

2. Price per unit of product is constant.
3. The storage cost per unit per year (H) is constant.
4. The ordering cost per order (S) is constant.
5. The time between orders is done and goods received (lead time, L) is constant.
6. There is no shortage of goods or return orders

Safety Stock

Safety Stock is the amount of finished goods inventory which is also referred to as a buffer stock. Safety stock is used to fulfill the demand of customer when uncertainty things happen suddenly. The equation for calculating safety stock are:

$$\text{Safety stock} = \text{safety factor} \times \text{standard deviation} \quad (5)$$

Standard deviation is the result of calculations that use the demand data during the period. The formula for calculating standard deviation:

$$S = \sqrt{\frac{\sum(x-\bar{x})^2}{n}} \quad (6)$$

The safety factor is a calculation of a safety factor that depends on the service level provided. In determining the service level, some companies specify different service levels for some types or categories of goods, for example:

Raw material: 100% service level
Goods program: 100% service level

Raw materials for:

Vital equipment: The service level of 99%
Essential equipment: The service level of 95%
Auxiliary equipment: The service level of 90%
Operational equipment: 85% service level

METHOD

The research methodology is derived from steps that carried out in the research—the steps starting from conducting the preliminary review, literature review, problem identification, problem formulation, data collecting, data processing, and analysis.

Problem observations were conducted to determine and observe real conditions that occur in related companies. The observation was also followed by interviews with the head of Procurement Planning and Control Division, the head of Production Planning and Control Division and employees of Production Planning and Control Division.

The problem is the stock of gypsum in PT Semen Padang. Sometimes PT Semen Padang is run out of gypsum stock, and that is dangerous because gypsum is the most important additive material for making cement. Without gypsum, the production process of cement will not be run smoothly. The formulation of the problem based on the identification of the problem is how to control the inventory of gypsum for the next period and is the cost of inventory that the company's spend is already optimal.

Data required to solve the problems of requirement planning and inventory control in PT Semen Padang are consist of primary data and secondary data.

a. Primary Data

Primary data is the data that taken from the interview. The first interview is done with the head of Procurement Planning and Control Division about the cost related to procurement of gypsum in PT Semen Padang such as ordering cost, holding cost and the lead time ordering gypsum. The second interview is done with the head of Inventory Planning and Control Division and Employee of Production Planning and Control Division about the importance of gypsum in PT Semen Padang. The last interview is done with the employee of the Production Planning and Control Division about the purchasing cost of gypsum.

b. Secondary Data

Secondary Data is the data from the Production Planning and Control Division in PT Semen Padang, the list of the data is as follow.

1. Historical Data Demand of Gypsum in 2014 and 2015
2. Purchasing Cost of Gypsum
3. Ordering Cost of Gypsum
4. Holding Cost of Gypsum

Historical data demand of gypsum is used to forecast the demand of gypsum for the next 24 months. Then determine the number of optimal ordering based on methods and calculate the inventory cost. The result is compared with the inventory cost that the company spends in PT Semen Padang to know whether the inventory cost is already optimal or not. The analysis is conducted on the data processing that has been done and refers to literature found on a theoretical basis.

RESULTS AND DISCUSSION

Data collection was done during the implementation of industrial training in PT Semen Padang. The data needed for the calculation are as follows. Data of gypsum historical demand PT Semen Padang in the year 2014 and 2015 can be seen in Figure 1.

Purchasing Cost of Gypsum

The purchasing cost of gypsum is 25 USD per ton. In rupiah the purchasing cost is Rp. 333,350.00 per ton. The cost of gypsum per year can be seen in Table 1.

Table 1. Purchasing Cost of Gypsum

Year	Purchasing cost
2014	Rp. 68,005,760,784.70
2015	Rp. 75,931,115,699.30

Ordering Cost of Gypsum

Estimation of ordering cost is 3 % of the purchasing cost per year. It is because the purchasing cost of gypsum is the cost until the gypsum arrives at the storage. So, the ordering cost that consists of transportation cost and the administration cost is included in the purchasing cost. The estimation of ordering cost can be seen in Table 2.

Table 2. Ordering Cost of Gypsum

Year	Ordering cost
2014	Rp. 170,014,401.96
2015	Rp. 189,827,789.25

Holding Cost of Gypsum

Holding cost is the estimation cost from the actual cost because the company did not know the exact number of the gypsum holding cost every year. The estimation of holding cost can be seen in Table 3.

Table 3. Holding cost of gypsum

Year	Holding Cost
2014	Rp. 98,719.60
2015	Rp. 98,223.48

Lead Time Ordering Gypsum

Lead Time is the interval of time between the ordering time with the arrival time of the material. Lead Time ordering gypsum is 30 days. The process to know the optimal inventory cost by using EOQ method is done by following steps below.

Plot Data of Gypsum Historical Demand

The first step for forecasting is to plot the data of historical demand. The purpose of the plot data is to see the pattern of the data to choose the right method that suit the pattern. The plot data of historical demand gypsum in PT Semen Padang shows in Figure 1.

Forecasting Method

There are for methods that used for the forecast in this solving problem, that are linear regression, exponential, cyclical and cyclical trends.

The Calculation of Forecasting Method Error

Forecasting method error is calculated using the Mean Absolute Percentage Error (MAPE) method. The error of forecasting method with the smallest error is the method chosen to perform forecasting next 12 periods. Recapitulation of error calculation of each method can be seen in Table 4.

Based on the recapitulation calculation error result, exponential forecasting method chosen as the forecasting method for next period forecast, because this method has the minimum error based on MAPE calculation (the smallest error).

Table 5. The result of EOQ method

	2014	2015	2016	2017
Ordering cost	Rp 170,014,401.96	Rp 189,827,789.25	Rp 179,921,095.61	Rp 179,921,095.61
Demand	204,007.08	227,781.96	281,505.64	332,47.23
Holding cost	Rp 98,719.60	Rp 98,223.48	Rp 98,471.54	Rp 98,471.54
Lot size order	26,508	29,672	32,073	34,856
Frequency	8	8	9	10

Table 4. Recapitulation of Error Calculation

No.	Forecasting Method	MAPE	Minimum
1	Regression Linear	0.1092	
2	Cyclic	0.1598	0.1053
3	Exponential	0.1053	
4	Trend Cyclic	0.106	

Forecasting Verification for the Selected Method

The purpose of verification is because there is a possibility of data forecasting results that outside of the control limits. Data which are outside the control limits should be discarded and do re-forecasting again.

Based on the first verification result there are 2 data that out of the control limit that should be discharged. Then do forecasting with the 22 data with the chosen forecasting method and continued to the second verification.

Based on the second verification result shows that there is no data outside the control limits, so the results can be used to forecast the demand for the next period. The result of forecasting using exponential method can be seen in Figure 4. Based on the forecast demand, then the inventory control was calculated using EOQ method.

The year 2016:

$$\begin{aligned}
 \text{EOQ} &= \sqrt{\frac{2AD}{h}} \\
 &= \sqrt{\frac{2 \times \text{Rp } 179,921,095.61 \times 281,505.64 \text{ ton}}{\text{Rp } 98,471.54}} \\
 &= 32,073 \text{ ton}
 \end{aligned}$$

$$\begin{aligned}
 \text{Frequency} &= \frac{D}{Q} \\
 &= \frac{281,505 \text{ ton}}{32,073 \text{ ton}} \\
 &= 8.78 \\
 &= 9 \text{ times}
 \end{aligned}$$

Year 2016:

$$\begin{aligned}
 \text{Inventory Cost} &= \text{Ordering Cost} + \text{Holding Cost} \\
 &= (9 \times \text{Rp } 179,921,095.61) + ((16,036.67 \text{ ton} + 15,834.303 \text{ ton}) \times \text{Rp } 98,471.54) \\
 &= \text{Rp } 4,757,673,813.48
 \end{aligned}$$

Table 6. The Inventory Cost of EOQ Method

Year	Ordering cost	Holding cost	Inventory cost
2014	Rp 1,360,115,215.69	Rp 11,305,769,680.83	Rp 12,665,884,896.5
2015	Rp 1,518,622,313.99	Rp 8,196,735,197.01	Rp 9,715,357,510.9
2016	Rp 1,619,289,860.45	Rp 3,138,383,963.04	Rp 4,757,673,813.5
2017	Rp 1,799,210,956.05	Rp 7,895,594,652.31	Rp 9,694,805,608.4

Safety Stock

The year 2016:

$$\text{Standard Deviation} = \sqrt{\frac{\sum_{i=1}^n (y' - \bar{y})^2}{n-1}}$$

$$= 1,122.69$$

Table 7. The Standard Deviation for Each Year

Year	Standard deviation
2014	7,180.31
2015	4,864.90
2016	1,122.69
2017	4,449.38

Lead Time = 30 days

Service Level (Z) = 100% - z

= 100% - 99%

= 2.5750 (From Normal Curve Table)

Year 2016:

Safety Stock

= Z x Standard Deviation x $\sqrt{\text{Lead time}}$

= 2.5750 x 1,122.69 x $\sqrt{30}$

= 15,834.303 ton

Table 8. The result of safety stock

Year	Safety stock (ton)
2014	101,270
2015	68,613.85
2016	15,834.30
2017	62,753.45

Reorder Point

Year 2016:

Reorder Point

= Safety Stock x (Lead time x Average used)

= 15,834.303 ton x (1 month x 23,458.80 ton)

= 39,293.10581 ton

Year 2017:

Reorder Point

= Safety Stock x (Lead time x Average used)

= 62,753.454 ton x (1 month x 27,706.02 ton)

= 90,459.47317 ton

Maximum Inventory

Year 2016:

Max Inventory

= Safety Stock + EOQ

= 15,834.303 ton + 32,073 ton

= 47,908 ton

Year 2017:

Max Inventory

= Safety Stock + EOQ

= 62,753.454 ton + 34,856 ton

= 97,610 ton

Inventory Cost in PT Semen Padang

To compare the inventory cost in the company and by using EOQ method, we must know both of inventory cost. Because of the inventory cost of PT Semen Padang is classified, there must be an estimation to know the number of total inventory cost. This company is using the Min-Max method to control the inventory of gypsum, so the estimation of the inventory cost is calculated using the Min-Max method.

Year 2014:

Safety Stock

= (Maximum used – Average of used) x Lead time

= (22,164 ton – 17,001 ton) x 1 month

= 5,163.51 ton

Min stock

= (Average of used x Lead time) + Safety stock

= (17,001 ton x 1 month) + 5,163.51 ton

= 22,164.10 ton

Max stock

= 2 x (Average of used x Lead time)

= 2 x ((17,001 ton x 1 month)

= 34,001.18 ton

Reorder Point

= Max stock – Min stock

= 34,001.18 ton – 22,164.10 ton

= 11,837.08 ton

Inventory Cost

= ((Total used/Reorder point) x Ordering cost) + (Holding cost x Total used)

= ((204,007.08 ton / 11,837.08 ton) x Rp 170,014,401.96) + (Rp 98,719.60 x 204,007.08 ton)

= Rp 23,069,623,760.92

Table 9. The Result of Using the Min-Max Method

	2014	2015	2016	2017
Safety stock	5,163.51	2,952.73	1,830.18	2,161.53
Minimum stock	22,164.10	21,934.56	25,288.98	29,867.55
Maximum stock	34,001.18	37,963.66	46,917.61	55,412.04
Reorder point	11,837.08	16,029.10	21,628.62	25,544.49
Inventory cost	Rp. 23,069,623,760.92	Rp. 25,071,089,876.70	Rp. 30,062,043,061.22	Rp. 35,080,802,308.82

Table 10. Comparison of Inventory Cost

Year	Inventory cost of the company	Inventory cost using EOQ	Difference	Presentation
2014	Rp. 23,069,623,760.92	Rp. 12,665,884,896.52	Rp. 10,403,738,864.39	45.10%
2015	Rp. 25,071,089,876.70	Rp. 9,715,357,510.99	Rp. 15,355,732,365.70	61.25%

Comparison of Inventory Cost of Company and Using Methods

The comparison between the inventory cost of the company and the inventory cost using method can be seen in Table 10. The analysis is done based on the results of data processing that has been done before. The first step to forecast demand is to plot the data historically. The purpose of the plot data is to see the pattern to determine the right method for forecasting the demand. Based on the plot data, forecasting methods that we can use are the Linear Regression method, cyclical method, Exponential method, and Cyclical Trends method.

Forecast error is the difference between the actual demand and forecast demand. This is useful when you want to determine if one forecasting method is better than another. From this problem, we used four different methods to determine the forecast demand for gypsum in the next period. So, the calculation of forecast error is to determine the best forecast method to use for forecasting the demand of next period. The method that is used to calculate the forecasting error in this problem is MAPE. In the calculation, the selected method is an Exponential method that has MAPE value 0.1053.

The next step after got the result of forecasting using the selected method is verification of the data. The purpose of the verification is to see whether the forecast demand interprets the actual demand based on the historical data of the company or not. The method that is used to verify the forecast model is the Moving Range Chart.

Based on the result of 1st verification, from the 24 data of forecast demand, 2 data are deleted because the residual value is outside the control limit, there are the 4th and 7th. For the 2nd verification, all the data is inside the control limit. So, no more data has to be thrown away, and the verification step is done. Then, forecast the next demand period by using the 22 data of the forecast data. The result of forecasting can be seen in Figure 4.

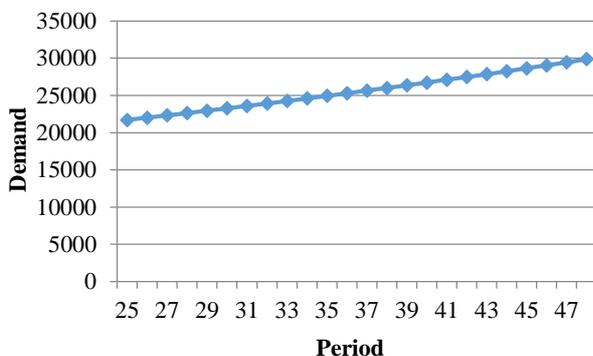


Figure 4. Demand Forecasting of Gypsum in PT Semen Padang

Figure 4 shows that the demand forecasting is getting higher for each period. This is because the selected method that is used to forecast the demand is the Exponential Method. Exponential method graph is always getting higher for the next period because it used for the trend data.

After getting the forecast demand, the inventory control of gypsum was calculated to meet the objective of the problem-solving. The method of inventory control that is used in this problem is EOQ. From data calculation, the result of gypsum usage based on production demand is 281,505.64 ton in 2016. Based on EOQ method, the value of EOQ is 32,073 ton. It means that the optimal amount of ordering gypsum is 32,073 ton for every order. The frequency is nine times. It means the optimal frequency that the company order gypsum is nine times in the year 2016. And the total inventory cost is Rp. 4,757,673,813.48. The amount of safety stock to be saved by the company as a level of extra stock that is maintained to mitigate the risk of stock outs or due to uncertainties in supply and demand is 15,834.303 ton. The reorder point, where the company must start to order gypsum is when the gypsum stock is in 39,293.10581 ton. The maximum inventory in the storage is 97,610 ton.

PT Semen Padang is using Min-Max method for the inventory control. Because of the inventory cost is classified, we used the min-max method calculation for the estimation of the company spend on inventory cost of gypsum. Based on the calculation in 2014, the inventory cost of the company is Rp. 23,069,623,760.92 and the inventory cost by using EOQ is Rp. 12,665,884,896.52, it has a difference about 45%. The purpose of EOQ is the order of quantity that minimizes the total of holding cost and ordering cost for the year. So, if the company using EOQ as a method for inventory control the company will save 45% of the total cost that the company spends in that year. It is also the same in the year 2015, the difference between the total costs in the company and using methods is 61%.

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CONCLUSIONS

Based on the analysis, the conclusions of this research are in 2016 by using EOQ method, the optimal order quantity is 32,073 ton per order, and the frequency is 9 times in a year with total cost Rp 4,757,673,813.48, and in 2017, the optimal order quantity is 34,856 ton per order and the frequency is 9 times in a year with total cost Rp. 9,694,805,608.36. The Inventory cost that is spent by the company is not optimal, because the company still can minimize the total inventory cost if they use the EOQ method.

REFERENCES

- [1] E. M. B. Aske and S. Skogestad, "Consistent inventory control," *Industrial & Engineering Chemical Research*, vol. 48, no. 24, pp. 10892–10902, 2009. <https://doi.org/10.1021/ie801603j>.
- [2] S. Ziukov, "A literature review on models of inventory management under uncertainty," *Business System and Economics*, vol. 5(1), pp. 26-35, 2015. <https://doi.org/10.13165/VSE-15-5-1-03>.
- [3] D. O. N.G. Hai, Z. H. E. N. G. Hao and L. Y. Ping, "Model predictive control for inventory management in supply chain planning," *Procedia Engineering*, vol. 15, pp. 1154-1159, 2011. <https://doi.org/10.1016/j.proeng.2011.08.213>.
- [4] R. Chaib, M. L. Bouanaka, A. Bellaouar, M. Benidir, and I. Verzea, "Determination of the efficiency of a means of production application in a chain of production," *Management of Technological Changes*, vol. 1, pp. 605–608, 2009.
- [5] A. Bacchetti, R. Plebani, N. Saccani, and A. Syntetos, "Spare Parts Classification and Inventory Management: a Case Study," *Salford Business School Working Papers Series*, vol. 408, 2010.
- [6] G. A. Keskin, S. I. Omurca, N. Aydin, and E. Ekinci, "A comparative study of production-inventory model for determining effective production quantity and safety stock level," *Applied Mathematical Modelling*, vol. 39(20), pp. 6359-6374.2015. <https://doi.org/10.1016/j.apm.2015.01.037>.
- [7] D. K. Chester, A. M. Duncan, and C. J. L. Dibben, "The importance of religion in shaping volcanic risk perception in Italy, with special reference to Vesuvius and Etna," *Journal of Volcanology Geothermal Research*, vol. 172(3–4), pp. 216–228, 2008. <https://doi.org/10.1016/j.jvolgeores.2007.12.009>.
- [8] M. Godichaud and L. Amodeo, "Economic order quantity for multistage disassembly systems," *International Journal of Production Economics*, vol. 199, pp. 16–25, 2018. <https://doi.org/10.1016/j.ijpe.2018.02.008>.
- [9] R. Kumar, "Economic Order Quantity (EOQ) Model," *Global Journal of Finance and Economic Management*, vol. 5, no. 1, pp. 2249–3158, 2016.
- [10] L. B. Schwarz, "The economic order-quantity (EOQ) model," *International Series in Operations Research and Management Science*, vol. 115, 2008, pp. 135–154. https://doi.org/10.1007/978-0-387-73699-0_8.
- [11] K. C. Land, "Forecasting," in *International Encyclopedia of the Social & Behavioral Sciences: Second Edition*, 2015. <https://doi.org/10.1016/B978-0-08-097086-8.10544-6>.
- [12] S. J. Taylor and B. Letham, "Forecasting at Scale," *The American Statistician*, vol. 72(1), pp. 37-45, 2018. <https://doi.org/10.7287/peerj.preprints.3190>.
- [13] C. C. Defee, B. Williams, W. S. Randall, and R. Thomas, "An inventory of theory in logistics and SCM research," *The International Journal of Logistics Management*, vol. 21(3), pp. 404-489, 2010. <https://doi.org/10.1108/09574091011089817>.
- [14] S. E. Sampson and M. Spring, "Customer Roles in Service Supply Chains and Opportunities for Innovation," *Journal of Supply Chain Management*, vol. 48(4), pp. 30-50, 2012. <https://doi.org/10.1111/j.1745-493X.2012.03282.x>.
- [15] E. Van Der Laan, M. Salomon, R. Dekker, and L. Van Wassenhove, "Inventory control in hybrid systems with remanufacturing," *Management Science*, vol. 45(5), pp. 733-747, 1999. <https://doi.org/10.1287/mnsc.45.5.733>.
- [16] J. S. Morris and R. J. Tersine, "A simulation comparison of process and cellular layouts in a dual resource constrained environment," *Computers & Industrial Engineering*, vol. 26(4), pp. 733-741, 1994. [https://doi.org/10.1016/0360-8352\(94\)90008-6](https://doi.org/10.1016/0360-8352(94)90008-6).
- [17] F. Lestari, Ulfah, Suherman, B. Azwar, and P. Fithri, "Combining ABC and VED analysis for managing medicine inventory (case study at community development elderly in Indonesia)," *International Journal on Advanced Science Engineering Information and Technology*, vol. 9(3), 2019. <https://doi.org/10.18517/ijaseit.9.3.7153>.
- [18] S. Assauri, *Manajemen Produksi dan Operasi*. Jakarta: Lembaga Penerbit Fakultas Ekonomi Universitas Indonesia, 2008.

NOMENCLATURE

- D = Demand
 Q = Lot size
 A = Ordering cost
 H = the holding cost to the purchase price/unit
 C = the price per unit of material
 B = reorder point
 ac = ce = interval between orders
 ab = cd = ef = lead time
 m = Number of average inventory
 x = The number of demand
 \bar{x} = The average of demand
 N = The number of the demand period