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Comparative Analysis of EOQ Method, POQ Method, and Min-Max Method in Controlling Inventory of Subsidized NPK Phonska Fertilizer Raw Materials at PT Petrokimia Gresik

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ABSTRACT

PT Petrokimia Gresik is the most comprehensive fertilizer manufacturer in Indonesia, and it produces a wide range of fertilizers and chemicals for agro-industry solutions. One of its products, NPK Phonska fertilizer, is always the product with the highest demand every year. In 2023, the demand for this fertilizer reached 1,972,380.55 tons. The main problem that often occurs is the overstocking and stocking out of raw materials. This condition not only results in increased storage costs but also threatens production continuity. Therefore, optimal inventory control is the company's main goal, which is to ensure the availability of raw materials in a timely manner and minimize costs. This study aims to find the most effective inventory control method in overcoming these problems. The EOQ (Economic Order Quantity) and POQ (Periodic Order Quantity) methods were chosen as alternative solutions. This research uses quantitative methods with data collection through field observations. The results showed that the most right inventory control method to reduce total inventory costs is the EOQ method, with a total cost of Rp7,043,999,215. This figure is lower than the POQ method of Rp11,071,943,308 and the Min-Max method used by the company of Rp23,217,085,977. The EOQ method is proven to be more efficient in managing inventory, resulting in cost savings of up to 69.7% or Rp16,173,086,762. Therefore, the application of the EOQ method is a good choice to be implemented in the company.

Keywords: *Raw Material Inventory, Inventory Control Methods, Economic Order Quantity (EOQ), Periodic Order Quantity (POQ), Minimum-Maximum (Min-Max)*

Introduction

The domestic agricultural sector currently supports national economic growth related to food security. In the third quarter of 2023, the growth of the agricultural sector was recorded at 1.46% (year-on-year) and contributed 13.57% to Gross Domestic Product (GDP) [1]This achievement shows the important role of the agricultural sector in supporting national food security. With the increasing population, agricultural productivity must continue to increase to meet the increasing need for food.

PT Petrokimia Gresik is the most complete fertilizer producer in Indonesia and is under the auspices of PT Pupuk Indonesia (Persero). The company has a production capacity of 6.5 million tons of fertilizer per year, including various types of fertilizers, including petroganic, ZK, Blending, NPK, NPK Kebomas, NPK Phonska, ZA, phosphate, and urea fertilizers. The company also produces several chemicals, including phosphoric acid, , sulfuric acid, aluminium fluoride, cement retarder, purified gysum, dry ice, liquid CO2, and hydrochloric acid [2].

The government has provided subsidized fertilizer assistance to farmers, especially NPK Phonska and urea fertilizers, to support crop production [3], [4]Fertilizers are an important component in crop production, as they help increase plant resistance to disease, improve plant quality, and increase yields. In 2023, the demand for subsidized fertilizers at PT Petrokimia Gresik reached 1,972,380.55 tons for NPK Phonska fertilizer and 664,213.90 tons for urea fertilizer. The type of subsidized fertilizer with the highest demand is NPK Phonska fertilizer.

However, this high demand poses challenges in controlling the inventory of raw materials, such as , sulfuric acid, phosphoric acid, and potassium chloride (KCL Merah), which are used to produce NPK Phonska fertilizer. In the inventory planning department of PT Petrokimia Gresik, a web-based application (PETRO PPIC) is available that allows employees to input and access data on product

inventory planning and management on a daily, monthly, and annual basis. Raw material inventory data during 2023 shows fluctuations in stock, with several months experiencing stockout and overstock conditions. Stockout conditions can lead to disruption of production and customer dissatisfaction, while overstock can incur high storage costs and the risk of damage to raw materials [5]. Therefore, it is important to control inventory to determine the optimal inventory level in order to minimize inventory costs [6].

To overcome this problem, PT Petrokimia Gresik currently uses the minimum-maximum method to control raw material inventory. This method sets minimum and maximum limits for inventory, which are used as a guide in determining the order quantity [5]-[9]. However, other alternatives are more effective, such as the EOQ (Economic Order Quantity) method, which aims to minimize total inventory costs by calculating the optimal order quantity based on ordering costs and storage costs [5]-[24]. In addition, the POQ (Periodic Order Quantity) method can also be considered because it focuses on a fixed ordering frequency [5]-[25].

The application of comparing the three inventory control methods has been carried out in several studies, including the first is a study comparing the EOQ, POQ, and Min-Max methods in controlling the inventory of Boeing 737NG aircraft components at PT Garuda Maintenance Facility, showing that the EOQ method is more optimal in reducing inventory costs, especially for very important class A components, compared to the Min-Max method previously used by the company [7]. In another study, it was mentioned that the EOQ, POQ, and Min-Max methods were evaluated to manage UPVC raw material inventory at PT XYZ. The analysis results show that the EOQ method is most optimal in minimizing total costs through setting the number and cycle of orders, compared to the Min-Max method previously used by the company, while POQ is considered for periodic ordering [11].

This research will evaluate the effectiveness of PT Petrokimia Gresik's inventory control method (Min-Max Method) by comparing several alternative methods, namely EOQ and POQ. The goal is to identify the right inventory control method for raw materials to reduce inventory costs and better meet farmers' fertilizer needs.

Research Methods

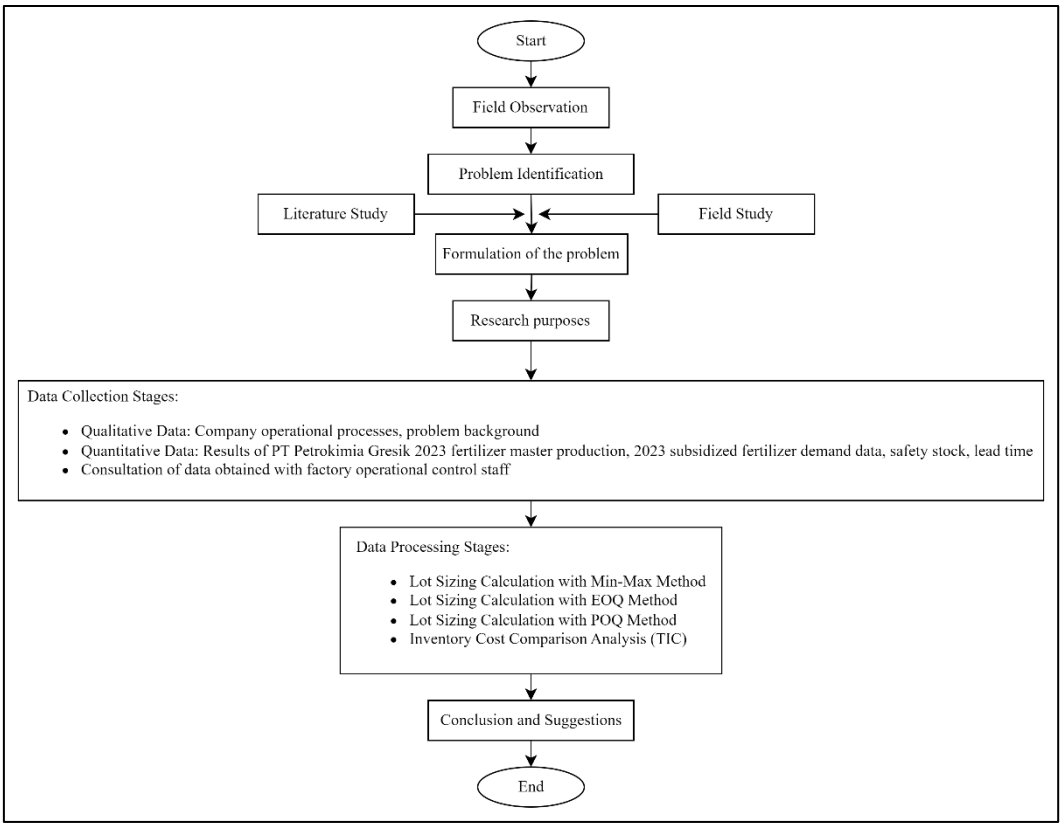

Figure 1 Research flowchart

This research was conducted at PT Petrokimia Gresik, which aims to find the right NPK Phonska raw material inventory control method for the company. Primary data collection in this study was carried out through field observations and interviews with operational control staff in the PPPE

section (Dept. Production Planning & Energy Management). Secondary data in the form of documents containing daily production data during 2023 was obtained from the company. The stages of determining the inventory control method for NPK Phonska fertilizer raw materials are carried out using a comparison of the total inventory cost between three methods, namely the Economic Order Quantity (EOQ) method, Periodic Order Quantity (POQ), and the Min-Max method (the method applied by the company today)..

The following is an explanation of the problem-solving solution:

Inventory Control

Inventory control itself is a process carried out to maintain inventory levels at an optimal level so that it can meet the company's needs without incurring excessive costs [28]. Inventory control is an activity carried out to regulate the optimal amount of inventory of goods in order to meet consumer demand at minimal cost [12].

Economic Order Quantity (EOQ)

EOQ is a method used to determine the optimal order quantity that minimizes the total cost of inventory, where these total costs include ordering costs and storage costs [5]-[24].

$$EOQ = \sqrt{\frac{2\ x\ D\ x\ S}{H}} \quad (1)$$

Information:
D = Annual demand
S = Ordering cost per one-time order
H = Holding cost per unit per year

Periodic Order Quantity (POQ)

POQ is an inventory control method that determines the optimal order quantity based on a certain time period, where this method focuses on setting the time interval between orders to match demand needs during that period [5]-[25].

The POQ method can be found using the following formula:

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

Information:
EOQ = *Economic order quantity* (ton)

For optimum order quantity:

$$Q = \frac{D}{Order\ Frequency\ Per\ Year} \quad (3)$$

Information:
Q = Quantity Order (ton)
D = Annual demand (ton)

Safety Stock

Safety Stock is an additional inventory that is important to maintain the smooth production process and prevent the occurrence of raw material stock shortages [24], [28]. The optimal safety stock level depends on several factors, such as demand variability, storage costs, and lead time. The safety stock formula with a Z-score is as follows:

$$SS = Z\ x\ \sigma\ x\ \sqrt{LT} \quad (4)$$

Information:
Z = Z-score value selected based on the desired service level
σ = Standard deviation of demand
LT = Lead Time or waiting time (month)

Reorder Point (ROP)

ROP is a reorder point that indicates when the company should reorder raw materials to ensure a smooth production process [24], [28].

$$ROP = (LT\ x\ D) + SS \quad (5)$$

Information:
LT = Lead Time (month)
D = Average demand per period (tons)
SS = Safety stock (tons)

Total Inventory Cost (TIC)

Total inventory cost (TIC) is the total cost incurred by the company for inventory, including storage costs and ordering costs [24], [28].

$$TIC = \left(\left(\frac{Q}{2}\right) x\ H\right) + \left(\left(\frac{D}{Q}\right) x\ S\right) \quad (6)$$

Information:
Q = Order quantity (tons)
H = Storage cost per unit per year (Rp)
D = Annual demand (tons)
S = Ordering cost per order (Rp)
(Q/2)*H = Average storage cost (Rp)
(D/Q)*S = Ordering cost (Rp)

Results And Discussion

At the data collection stage, data was obtained from the PPPE section (Production Planning & Energy Management Dept.). The data taken is the Master Production Results of PT Petrokimia Gresik during the 2023 period. Historical data on raw material requirements for NPK Phonska subsidized fertilizer products are shown in Table 1.

Table 1 Historical data on raw material requirements for NPK Phonska fertilizer during 2023

No	Month	Raw Material Quantity (Ton)			
		Ammonia	**Sulfuric Acid**	**Phosphoric Acid**	**Potassium Chloride**
1	January	23,483.53	51,939.55	46,287.97	45,257.97
2	February	19,713.55	39,381.48	38,638.33	34,633.10
3	March	15,256.19	28,723.98	27,183.77	26,780.73
4	April	16,942.08	39,186.82	37,781.03	31,411.94
5	May	17,480.82	37,085.94	35,758.78	28,782.65
6	June	13,782.24	35,186.20	32,293.65	30,477.34
7	July	13,126.89	30,802.93	29,612.50	25,633.30
8	August	9,032.36	23,231.83	25,722.45	15,879.16
9	September	5,550.99	13,198.27	18,490.81	14,004.88
10	October	6,892.98	17,024.50	19,863.96	17,949.79
11	November	7,759.15	17,652.99	24,617.44	17,535.06
12	December	13,764.63	27,194.85	30,903.67	17,891.94
TOTAL		**162,785**	**360,609**	**367,154**	**306,238**
AVERAGE		**13,565**	**30,051**	**30,596**	**25,520**
Maximum		23,483.53	51,939.55	46,287.97	45,257.97
Minimum		5,550.99	13,198.27	18,490.81	14,004.88

Source: (PT Petrokimia Gresik, 2024)

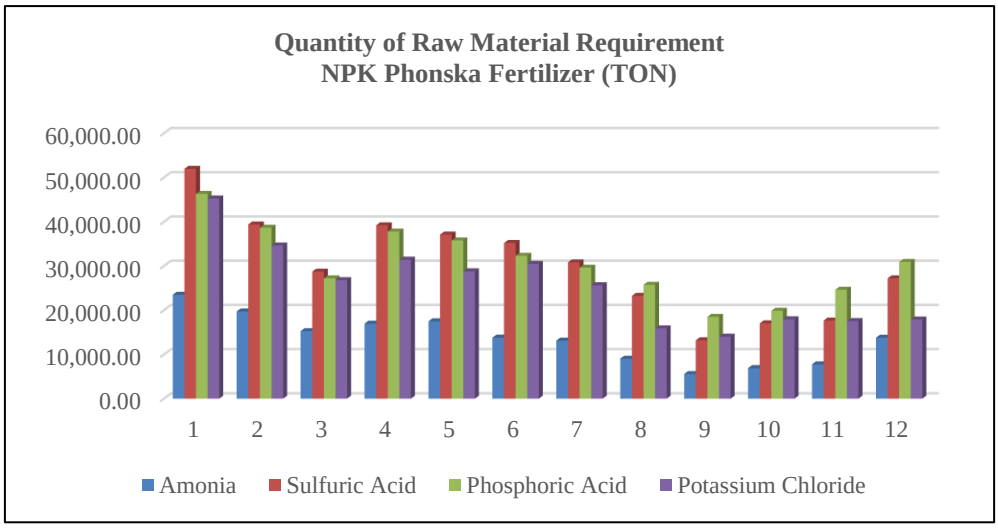

Figure 2 Graph of quantity of raw material requirement for NPK Phonska fertilizer

Sumber: (PT Petrokimia Gresik, 2024)

Table 1 and Figure 1 above show that demand fluctuates each month. Variations in demand can result in significant shifts in costs, which in turn affect inventory control decisions and company policies.

Table 2 presents the company's estimated ordering cost (S) for each type of raw material for NPK Phonska subsidized fertilizer at PT Petrokimia Gresik. The ordering cost includes several components, namely import invoices, administrative costs at the port of loading, shipping costs, warranty costs (cargo insurance), unloading costs, and raw material procurement costs.

Table 2 Ordering cost of NPK Phonska fertilizer raw materials

Raw Material	Total Cost/Order	Ship Capacity (ton)
Ammonia	Rp13,231,690	8,600
Sulfuric Acid	Rp12,308,549	20,000
Phosphoric Acid	Rp24,617,098	10,000
Potassium Chloride	Rp46,157,058	25,000

Source: (PT Petrokimia Gresik, 2024)

Table 3 shows the company's estimated storage cost (H) for each raw material of NPK Phonska subsidized fertilizer at PT Petrokimia Gresik, which is 17% of the purchase price of each raw material.

Table 3 Storage cost of NPK Phonska fertilizer raw materials

Raw Material	Total Cost / Ton
Ammonia	Rp552,989
Sulfuric Acid	Rp36,409
Phosphoric Acid	Rp618,320
Potassium Chloride	Rp1,115,539

Source: (PT Petrokimia Gresik, 2024)

Data Processing According to Company Policy

PT Petrokimia Gresik controls raw material inventory with the Min-Max method, which sets minimum and maximum limits. If the inventory reaches the minimum limit, the company orders new raw materials and stops if it reaches the maximum limit.

Table 4 shows the specific value for each raw material based on the calculation of inventory control with the Min-Max method.

Table 4 Raw Material Data Processing Results (Min-Max)

Data Processing	Ammonia	Sulfuric Acid	Phosphoric Acid	Potassium Chloride

Safety stock (ton)	1,322.41	9,485.13	15,691.77	14,474.64
Minimum Stock (ton)	3,131.14	22,507.14	46,287.97	33,189.18
Maximum Stock (ton)	4,939.86	35,529.14	76,884.17	51,903.72
Q (ton)	1,808.73	13,022.00	30,596.20	18,714.54
Q lot (ship unit)	1	1	4	1
Frekuensi (times)	90	28	12	16
Re-Order Point (ton)	3,131.14	22,507.14	46,287.97	33,189.18

Based on the results of the above calculations, the total inventory costs incurred by the company for procuring raw materials can be determined. The inventory costs are shown in Table 5.

Table 5 Inventory Cost Calculation Results (Min- Max)

Cost Components (Rp)	Ammonia	Sulfuric Acid	Phosphoric Acid	Potassium Chloride
Ordering Cost	Rp1,190,852,109	Rp340,852,124	Rp295,405,174	Rp755,297,321
Storage Cost	Rp500,103,323.13	Rp237,057,030.47	Rp9.459,119,688.76	Rp10,438,399,205.77
Inventory Cost	Rp1,690,955,432	Rp577,909,155	Rp9,754,524,863	Rp11,193,696,527
Total (Rp)	**Rp23,217,085,977**			

Based on company policy, the total cost of raw material inventory for the manufacture of NPK Phonska fertilizer, which includes ordering costs and storage costs, is **Rp23,217,085,977**.

Data Processing with the EOQ Method

If using EOQ to control the inventory of raw materials for NPK Phonska fertilizer in the company, here is an example of a calculation for Ammonia (NH3):

$$EOQ = \sqrt{\frac{2\ x\ D\ x\ S}{H}} = \sqrt{\frac{2\ x\ 162{,}785.40\ x\ Rp13{,}231{,}690}{Rp552{,}989}} = 2{,}791.08 \text{ ton}$$

The same calculation process also applies to other raw materials.

Table 6 shows the specific value for each raw material based on the calculation of inventory control with the EOQ method.

Table 6 Raw Material Data Processing Results (EOQ)

Data Processing		Sulfuric Acid	Phosphoric Acid	Potassium Chloride
EOQ (ton)	2,791.08	15,614.73	5,406.93	5,034.09
Q lot (ship unit)	2	2	6	4
Demand Frequency	29	12	11	15
Safety stock (ton)	3,154.97	11,689.46	12,833.90	12,565.24
Re-Order Point (ton)	4,963.70	24,711.47	43,430.10	31,279.77

The results of the above calculations can determine the total inventory costs incurred by the company for procuring raw materials. The inventory costs are shown in Table 7.

Table 7 Inventory Cost Calculation Results (EOQ)

Cost Components (Rp)		Sulfuric Acid	Phosphoric Acid	Potassium Chloride
Ordering Cost	Rp385,859,138	Rp142,127,929	Rp278,601,313	Rp701,965,765
Storage Cost	Rp771,718,275.78	Rp284,255,857.30	Rp1,671,607,879.01	Rp2.807,863,058.31
Inventory Cost	Rp1,157,577,414	Rp426,383,786	Rp1,950,209,192	Rp3,509,828,823
Total (Rp)	**Rp7,043,999,215**			

The total cost of raw material inventory for the manufacture of NPK Phonska fertilizer using the EOQ inventory control method which includes ordering costs and storage costs is **Rp7,043,999,215.**

Data Processing with POQ Method

If using POQ for controlling the inventory of NPK Phonska fertilizer raw materials in the company, here is an example of calculation for (NH3):

$$POQ = \frac{EOQ}{Average\ Demand} = \frac{2{,}791.08\ ton}{13{,}565\ ton/bulan} = 0.2056 \text{ bulan x } 30 = 6.17 \text{ hari}$$

Then to determine the frequency of orders in 1 year is as follows:

- $Order\ frequency\ per\ month = \frac{1\ year}{POQ\ month} = \frac{1\ year}{0.2056} = 4.87\ times\ per\ month$
- $Order\ frequency\ per\ year = \frac{365\ days}{POQ\ days} = \frac{365}{6.17} = 59.13\ times\ per\ year$

The same calculation process also applies to other raw materials.

Table 8 shows the specific value for each raw material based on the calculation of inventory control with the POQ method.

Table 8 Raw Material Data Processing Results (POQ)

Data Processing		Sulfuric Acid	Phosphoric Acid	Potassium Chloride
Demand 1 Year (ton)	162,785	360,609	367,154	306,238
Average Demand (ton)	13,565	30,051	30,596	25,520
POQ (days)	6.17	15.59	5.30	5.92
Order Frequency	59.13	23.41	68.85	61.68
Q (ton)	2,752.84	15,400.83	5,332.87	4,965.13

The results of the above calculations can determine the total inventory costs incurred by the company for procuring raw materials. The inventory costs are shown in Table 9.

Table 9 Inventory Cost Calculation Results (POQ)

Cost Components (Rp)		Sulfuric Acid	Phosphoric Acid	Potassium Chloride
Ordering Cost	Rp782,436,585	Rp288,203,855	Rp1,694,824,655	Rp2,846,861,156
Storage Cost	Rp761,146,793	Rp280,361,941	Rp1,648,709,141	Rp2,769,399,181
Inventory Cost	Rp1,543,583,378	Rp568,565,797	Rp3,343,533,796	Rp5,616,260,337
Total (Rp)	**Rp11,071,943,308**			

The total cost of raw material inventory for the manufacture of NPK Phonska fertilizer using the POQ inventory control method, which includes ordering costs and storage costs, is **Rp11,071,943,308.**

Analysis of Data Processing Results

This analysis aims to identify potential company savings by comparing the EOQ and POQ methods to the Min-Max method used today. Tables 5, 7, and 9 show the total inventory costs from January to December 2023 for the three methods. The results of the three are presented in Table 10.

Table 10 Comparison of total inventory cost

Lot Sizing Method	Total Inventory Cost (IDR)
Min-Max	Rp23,217,085,977
EOQ	Rp7,043,999,215
POQ	Rp11,071,943,308

From Table 10, it is found that the inventory control method with the minimum total inventory cost value is the EOQ method, with the savings obtained compared to the Min-Max method applied by the company as:

- $\text{TIC Savings Percentage} = \frac{difference\ between\ company\ TIC\ and\ EOQ}{Company\ TIC}\ x\ 100\%$
$$= \frac{\text{Rp23,217,085,977} - \text{Rp7,043,999,2154}}{\text{Rp23,217,085,977}} x\ 100\% = 69.7\%$$
- $\text{Cost TIC Savings} = 69.7\%\ x\ Rp23{,}217{,}085{,}977 = Rp16{,}173{,}086{,}762$

Based on the calculation results, the application of the EOQ method to control the inventory of raw materials for subsidized NPK Phonska fertilizer is highly recommended. This is because the EOQ method has been proven to reduce total inventory costs to **Rp16,173,086,762**. This benefit is obtained through optimizing the amount of ordering and storage of raw materials, thereby minimizing associated costs, such as storage, ordering, and the risk of stock shortages.

Conclusion

The research conclusion shows that the Economic Order Quantity (EOQ) method is the most optimal for controlling the inventory of subsidized NPK Phonska fertilizer raw materials, with the lowest total inventory cost of Rp7,043,999,215, much more efficient than the Min-Max and POQ methods. EOQ resulted in cost savings of 69.7% or Rp16,173,086,762 compared to company policy. The optimal order quantity (Q) is 2,791.08 tons for 15,614.73 tons for Sulfuric Acid, 5,406.93 tons for Phosphoric Acid, and 5,034.09 tons for potassium chloride. The reorder point (ROP) amounts to 104,385.03 tons, including 4,963.70 tons for, 24,711.47 tons for Sulfuric Acid, 43,430.10 for Phosphoric Acid, and 31,279.77 for potassium chloride. And the amount of safety stock is 40,243.57 tons. Suggestions given include evaluation of inventory policies, review of the optimal number of orders, and consideration of alternative methods for the company's future needs. This research is expected to enrich the theory of inventory control with EOQ, POQ, and Min-Max, as well as relevant modifications, such as integration of these inventory control methods with hybrid models that consider costs and seasonal demand, analysis of historical data, and use of ERP systems for automated recommendations.

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