



Optimization Strategy for Fertilizer Inventory Control Based on Economic Order Quantity (EOQ) and Period Order Quantity (POQ) to Enhance Efficiency and Profitability (Case Study: PT Pupuk Indonesia)

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Abstract

Fertilizer is a critical input for agricultural productivity, and PT Pupuk Indonesia (Persero), Indonesia's integrated fertilizer holding company, has faced stock shortages, inventory record discrepancies, and late order fulfillment, so better inventory planning has direct operational and economic value. This study applies ABC analysis, Economic Order Quantity (EOQ), and Period Order Quantity (POQ) to 15 types of fertilizer with company data of January to December 2024 (annual sales of 586 million kg worth Rp5.44 trillion). EOQ gives the order quantity and frequency that balance ordering and holding costs, and POQ expresses the same lot size as an ordering interval for periodic ordering, so both were used and compared; safety stock and reorder points cover demand variability. ABC analysis identified five Group A fertilizers (72.76% of the investment value). The EOQ and POQ order quantities are identical, and the higher cost of POQ equals the holding cost of its safety stock, so the two methods are equivalent in lot size. Against the company's quarterly ordering, EOQ reduces the total inventory cost of the 15 fertilizers from Rp127,980,124 to Rp108,330,164 (15.35%) and that of Group A from Rp69,464,373 to Rp61,668,354 (11.22%). The savings depend strongly on the holding cost rate, assumed to be 0.01% of the price. The company is recommended to adopt EOQ order quantities with reorder points for Group A, to apply safety stock consistently, and to validate the holding cost rate.

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1. Introduction

Inventory is defined as a collection of products owned by a company to support the production or sales process, consisting of raw materials, work-in-progress, and finished goods ready for sale to customers (P. Rahayu & Juliani, 2019). Inventory management is crucial for controlling costs and improving efficiency in business. Supply challenges arise when companies strive to ensure the availability of raw materials in the right quantity and at the right time to meet future market demand (Bachtiar, 2017). Errors in evaluating the order quantity of raw materials based on actual needs can lead to losses such as decreased quality, interest, and storage costs of raw materials (Bisri & Andesta, 2023).

The agricultural sector is a primary focus in enhancing food security and the economy in various countries (S. A. Rahayu, 2024). Fertilizers are a critical input for increasing crop productivity. However, inventory imbalances can lead to financial losses, reduced yields, or environmental impacts, necessitating analytical planning that includes determining the order quantity and reorder timing. Careful planning can prevent product shortages and unplanned procurement of products. Therefore, appropriate methods such as Always Better Control (ABC), often referred to as Pareto analysis, Economic Order Quantity (EOQ), Period Order Quantity (POQ), and Reorder Point (ROP) are required. The ABC analysis method is used to determine the priority of products that need to be controlled, while the EOQ and POQ methods help determine the right order quantity. Meanwhile, the ROP and Safety Stock methods assist in determining the right timing for reorder (Rizky et al., 2017).

Improvements in efficiency and profitability in inventory management are greatly influenced by effective stock management strategies. The Economic Order Quantity (EOQ) and Periodic Order Quantity (POQ) methods can assist companies in determining the optimal order quantity and timing, as effective inventory control allows companies to minimize ordering and storage costs. By implementing EOQ, companies can identify the most efficient order volume, which is the point at which total ordering and storage costs are at their lowest. This helps reduce operational costs and avoid the risks of overstocking or understocking that can hinder production and sales.

Meanwhile, POQ provides a flexible approach to dealing with demand fluctuations, as ordering is done at specific time intervals. Thus, the POQ method allows for periodic stock adjustments to anticipate changes in market demand volume. The optimization of both methods can enhance supply chain efficiency, accelerate responses to market dynamics, and ultimately have a positive impact on increasing company profits. Therefore, the implementation of inventory control strategies such as EOQ and POQ can lead to cost savings, reduce resource waste, and improve overall profitability, thereby enhancing business competitiveness.

Research comparing the EOQ, POQ, and Min-Max methods was previously conducted by (Bisri & Andesta, 2023). Based on the calculations, the EOQ method proved to be the most effective in minimizing total costs. This method resulted in the lowest order quantity and inventory costs compared to other methods, with an ordering frequency of 11 times per year and a total cost of Rp4.107.914 per year. Research on the use of the ABC and EOQ methods was also conducted by (Pramesti, 2023), which found that for 26 types of medicines, the EOQ method resulted in a cost of Rp288.151,83, saving 70,12 percent of the total inventory expenses incurred by Apotek Bandar Gerbang. Further research was conducted by (Rizky et al., 2017) using the EOQ, POQ, and Min-Max methods to control fertilizer inventory, which found that the EOQ method had a minimum risk level compared to the POQ method, with an ordering frequency of 42 times per year and an order quantity of 26 kg, resulting in total expenditures of Rp54.067.473.

Internationally, Watanabe et al. (2023) combined ABC analysis and EOQ for cleaning supplies in Thailand and found that ordering at the EOQ would reduce inventory expenses by 34%, although only 6 of the 16 Group A items could be applied because of minimum purchase quantities set by suppliers. Samal et al. (2022) analyzed inventory management of agro-based industries with EOQ and EPQ models, and Liao and Li (2021) extended the EOQ model to a closed-loop supply chain under market uncertainty. These studies compare an optimized policy with the current one, but they do not examine why EOQ and POQ differ in cost or how sensitive the savings are to the assumed holding cost, and, to the authors' knowledge, they do not cover a fertilizer holding company with 15 product types.

The research object at PT Pupuk Indonesia (Persero) is the planning and control practices of subsidized and non-subsidized fertilizer inventory at the distributor and retail kiosk levels. The data collection process for this study was conducted directly through in-depth interviews with administrative staff and sales support monitoring and evaluation personnel in Region 1. Pupuk Indonesia currently utilizes several methods in stock management, including the Stock Monitoring System, Distribution Planning and Control System (DPCS), and the Retail Management System (RMS), also known as Rekan. However, there are still several operational issues, including limited fertilizer availability in certain areas, making it difficult for distributors to meet sales quotas. In terms of storage, warehouses face various challenges, including the risk of physical product damage due to humidity, extreme temperatures, and sunlight exposure, as well as difficulties in inventory recording that lead to stock discrepancies and inaccurate data.

The urgency of this research follows from the scale of the operation and the problems reported by the company. In 2024 the 15 types of fertilizer analyzed had annual sales of 586 million kg worth Rp5.44 trillion, so that an order policy that is not calculated is applied to a very large flow of goods. The company reports limited availability in some areas, difficulty in meeting sales quotas, physical damage from humidity and temperature, and recording problems that give stock discrepancies and inaccurate data. These problems call for an order policy that balances ordering costs, holding costs, and the risk of shortage.

EOQ and POQ were used together because they answer two questions on the same demand data. EOQ gives how much to order and how often per year, which suits an order-point policy based on a reorder point, whereas POQ

converts the same lot size into an ordering interval, which suits the periodic distribution planning of the company (Nur Sany et al., 2023). Comparing them shows whether the choice of method changes the lot size or the cost. ABC analysis was added to focus control on the few fertilizers with the largest investment, and safety stock and the reorder point were added because demand varies from month to month.

The novelty of this study is therefore threefold: (1) the application of ABC, EOQ, POQ, safety stock, and reorder point to 15 fertilizer types of a state-owned fertilizer holding company; (2) the explicit comparison of EOQ and POQ, which shows that their lot sizes are identical and that their cost difference comes from the treatment of safety stock; and (3) the evaluation of the savings against the company's ordering policy, including their sensitivity to the holding cost rate.

This study aims to optimize the control of fertilizer inventory at PT Pupuk Indonesia. The research questions are: (1) which fertilizers are the priority according to ABC analysis; (2) what are the order quantities, order frequencies, safety stocks, and reorder points; (3) how do EOQ and POQ compare in lot size and total cost, and how much do they save compared with the company's current ordering; and (4) what recommendations follow for the company?

2. Method

The research followed nine steps. (1) Data collection: the 2024 sales quantity (kg) and price of 15 fertilizer types, the ordering cost (Rp1,000,000 per order), the holding cost rate (0.01% of the annual selling price), and the lead time (four days) were obtained from interviews with administrative staff and the sales support monitoring and evaluation staff of Region 1, and from company records. (2) ABC analysis: the fertilizers were ranked by investment value, the product of the sales quantity and the price, and classified into Groups A, B, and C. (3) Lilliefors normality test of the monthly demand of each fertilizer, to support the use of the normal distribution in the safety stock. (4) EOQ: the optimal order quantity and the order frequency were calculated. (5) POQ: the ordering interval and the order quantity were calculated. (6) Safety stock and reorder point: the safety stock was calculated for a 5% stockout probability, and the reorder point from the safety stock and the demand during the lead time. (7) Total inventory cost: the cost of the EOQ policy, the POQ policy (with safety stock), and the company's policy of four orders per year was calculated. (8) Comparison: the policies were compared for all 15 fertilizers and for Group A, and the effect of the safety stock and of the holding cost rate was examined. (9) Conclusions and recommendations.

2.1 Always Better Control (ABC)

The ABC method, also known as the Pareto method, classifies inventory into three categories. This method is useful for focusing company management on determining which types of items have priority in inventory. The ABC analysis indicates that the treatment of items should not be uniform based on their price. According to the ABC analysis or Pareto principle, items are classified into three main categories (Guslan & Saputra, 2020). Class A (80-20) items represent about 20% of the total inventory but account for approximately 80% of the total annual inventory costs. Class B (15-30) represents about 30% of the total inventory and absorbs around 15% of the total annual inventory costs (after Class A). Class C (5-50) accounts for about 5% of the total inventory costs in a year (excluding Classes A and B) and consists of approximately 50% of the total inventory quantity. The determination of investment value can be established by calculating the selling price.

$$\text{Investment Value} = \text{Total Sales} \times \text{Price}$$

2.2 Economic Order Quantity (EOQ)

Economic Order Quantity (EOQ) is a management method that assists in decision-making regarding the appropriate purchase amount and order quantity, with the aim of minimizing total costs, which include ordering and storage costs. Therefore, to calculate the purchase amount, it is necessary to consider additional costs, ordering costs, storage costs, and the average inventory size. According to (Watanabe et al., 2023), EOQ is a stock management method aimed at reducing total ordering and storage costs. The resulting item is the optimal purchase quantity as it yields minimum costs. The formula for calculating Economic Order Quantity (EOQ) according to (Watanabe et al., 2023) is as follows:

$$Q^{*(2)} = \frac{2DS}{H}$$

$$Q^* = \sqrt{\frac{2DS}{H}}$$

By using equation (1), the number or frequency of orders (F) over a given period can be calculated as follows (Watanabe et al., 2023):

$$F = \frac{D}{Q^*} \quad (2)$$

2.3 Period Order Quantity (POQ)

The POQ method is a lot-sizing technique used to determine the number of demand periods to include in each order (Nur Sany et al., 2023). It is similar to the EOQ method, with the key difference being the conversion of order quantity into an ordering time interval, yielding consistent order intervals. POQ can be calculated using the following formula (Nur Sany et al., 2023):

$$POQ = \sqrt{\frac{2 \times S}{D \times H}} \quad (3)$$

To calculate the optimal order quantity:

$$Q = D \times POQ \quad (4)$$

Because the ordering interval is the inverse of the order frequency, $POQ = 1/F = Q^*/D$, the POQ order quantity $Q = D \times POQ$ is equal to the EOQ. The two methods therefore give the same lot size, and they differ only in how it is expressed (a quantity or an interval) and in the cost items included, such as the safety stock.

2.4 Safety Stock

Safety stock is the minimum amount of materials that a company must maintain to prevent supply delays and avoid production stoppages. If the safety stock cannot anticipate uncertainties, it will result in stockouts, which occur when the demand exceeds the amount of inventory in the storage warehouse, leading to a longer than expected lead time. (Pramesti, 2023).

Safety stock is determined using statistical analysis by considering the deviations that have occurred between the forecasted usage of raw materials and the actual usage, allowing for the calculation of the standard deviation. The formula for standard deviation is as follows:

$$SD = \sqrt{\frac{\sum(x - \bar{x})^2}{N}} \quad (5)$$

The formula used to calculate safety stock is as follows:

$$\text{Safety Stock} = \text{Standard Deviation} \times \text{Safety Factor}$$

2.5 Lead Time

Lead time is the period required from the moment an order is placed until the goods arrive. The duration between ordering and receiving the goods, also known as lead time or delivery time, can range from short, such as a few hours, to longer, such as several months.

2.6 Reorder Point (ROP)

The reorder point is the threshold that indicates that a company or business entity needs to reorder goods or materials to maintain a stable and controlled supply condition. The reorder point occurs when the amount of inventory available in stock is continuously decreasing. Therefore, in inventory management, determining the reorder point is key to preventing stockouts and overstock situations.

By taking safety stock into account, the formula for calculating the reorder point is as follows: (Pramesti, 2023):

$$ROP = SS + (LT \times d) \quad (6)$$

If the reorder point (ROP) is less than the order quantity (Q) or $ROP < Q$, then there will be no inventory shortage. Conversely, if the reorder point (ROP) is greater than the order quantity, or $ROP > Q$, then there will be an inventory shortage with each order.

2.7 Total Inventory Cost

The optimal total inventory cost is the sum of the total ordering cost and the total holding cost. The formula for calculating the total inventory cost (TIC), is as follows (Watanabe et al., 2023):

To determine the total inventory cost using the EOQ method, the following applies:

$$TIC = Holding Cost + Ordering Cost$$

$$TIC EOQ = \left(\frac{D}{Q^*}\right) \times S + \left(\frac{Q^*}{2}\right) \times H$$

$$TIC EOQ = (n \times S) + (\bar{D} \times H) \quad (7)$$

To determine the total inventory cost using the POQ method, the following applies:

$$TIC POQ = Holding Cost + Ordering Cost$$

$$TIC POQ = \frac{S}{POQ} + \left(\frac{Q}{2} + SS\right) \times H \quad (8)$$

2.8 Lilliefors Normality Test

Normality testing is conducted to determine whether the collected data has a normal distribution or not. This means that good and accurate data has a normal distribution pattern, which does not deviate too much to the right or left, resembling a bell shape. The hypothesis proposed in this test is that H_0 represents a sample with a normal distribution, and H_1 represents a sample that does not have a normal distribution.

3. Results and Discussion

3.1. Fertilizer Cost Data

The fertilizer cost data include the price per kilogram of each of the 15 types of fertilizer, the ordering cost, and the holding cost. Based on interviews with the company, the ordering cost is Rp1,000,000 per order, and the holding cost per kilogram of fertilizer is 0.01% of the annual selling price.

3.2. ABC Analysis

Data analysis uses the ABC analysis method by sorting the quantity of utility, then grouping the types of goods to determine which type of fertilizer should be prioritized. The results of the ABC analysis are as follows:

Table 1. Results of ABC Analysis Based on Fertilizer Sales at PT Pupuk Indonesia in 2024

No	Fertilizer Name	Total Sales (kg)	Price (Rp.)	Investment Amount (Rp)	Investment Value (%)	Cumulative	Category
1	Urea Petro	142,292,776	9,700	1,380,239,927,200	25.378	25.378	A
2	Urea Nitrea	92,612,896	10,123	937,520,346,208	17.238	42.616	A
3	Urea PIM	63,128,463	9,000	568,156,167,000	10.447	53.063	A
4	NPK Pusri	40,971,400	13,150	538,773,910,000	9.906	62.969	A
5	SP-26 Petro	36,740,508	14,500	532,737,366,000	9.795	72.764	A
6	Urea Pusri Prill	60,892,381	7,560	460,346,400,360	8.464	81.229	B
7	Urea Daun Buah	46,272,521	7,750	358,612,037,750	6.594	87.822	B
8	NPK pelangi	22,156,707	8,260	183,014,399,820	3.365	91.187	B
10	NPK Majemuk Kujang	17,950,634	8,725	156,619,281,650	2.880	94.067	B
11	NPK Kebomas	28,483,267	5,376	153,126,043,392	2.815	96.883	C
12	Phosgreen	21,794,532	4,200	91,537,034,400	1.683	98.566	C
13	ZA Plus Petro	6,557,238	6,400	41,966,323,200	0.772	99.337	C
9	ZA Kujang	3199468	5,450	17,437,100,600	0.321	99.658	C
14	ZA Petro	3199468	5,400	17,277,127,200	0.318	99.976	C
15	SP-36 Petro	135,135	9,800	1,324,323,000	0.024	100.000	C
Total		586,387,394		5,438,687,787,780			

Based on Table 1, the classification of each type of fertilizer according to its category is obtained. The results of the grouping of fertilizers based on the ABC analysis are presented in the following table:

Table 2. Results of Fertilizer Grouping at PT Pupuk Indonesia Based on ABC Analysis

Group	Number of fertilizers	Investment value (Rp.)	Investment value percentage (%)	Percentage of fertilizer quantity (%)
A	5	3,957,427,716,408	72.76	33.33
B	4	1,158,592,119,580	21.30	26.67
C	6	322,667,951,792	5.93	40.00
Total	15	5,438,687,787,780	100	100.00

Table 2 shows that Group A has five types of fertilizer (33.33% of the types) with the highest investment, Rp3,957,427,716,408, which is 72.76% of the total investment of the 15 types (Rp5,438,687,787,780). Group B has four types (26.67%) with an investment of Rp1,158,592,119,580 (21.30%), and Group C has six types (40.00%) with an investment of Rp322,667,951,792 (5.93%). Group A thus holds less than 80% of the value with a third of the types, a weaker concentration than in the usual Pareto pattern.

3.3. Lilliefors Normality Test

The Lilliefors normality test is conducted to determine whether the data used is normally distributed or not, thereby minimizing errors in data processing. The results of the normality test on 15 types of fertilizer indicate that all data meet the assumption of normal distribution, allowing the calculations using the EOQ and POQ methods to proceed. An example of the normality test calculation for one type of fertilizer is the petro urea fertilizer.

Table 3. Normality Test for Petro Urea Fertilizer

No	X _i	(xi-x) ²	Z _i	F(Z _i)	S(Z _i)	F(Z _i)-S(Z _i)
1	7,890,416	15,739,590,954,102	-1.2900	0.0985	0.0833	0.0152
2	8,451,007	11,605,770,683,325	-1.1077	0.1340	0.1667	0.0327
3	9,762,334	4,390,689,984,540	-0.6814	0.2478	0.2500	0.0022
4	10,334,963	2,318,823,397,003	-0.4952	0.3102	0.3333	0.0231
5	10,466,890	1,934,439,614,508	-0.4523	0.3255	0.4167	0.0911
6	10,912,705	893,074,770,693	-0.3073	0.3793	0.5000	0.1207
7	11,159,776	487,141,647,328	-0.2270	0.4102	0.5833	0.1731
8	11,670,061	35,220,154,013	-0.0610	0.4757	0.6667	0.1910
9	12,094,235	55,933,984,347	0.0769	0.5306	0.7500	0.2194
10	15,995,113	17,117,927,055,669	1.3453	0.9107	0.8333	0.0774
11	16,054,212	17,610,449,985,707	1.3645	0.9138	0.9167	0.0029
12	17,501,064	31,847,203,586,667	1.8350	0.9667	1.0000	0.0333
Total		142,292,776				
std		3,075,360.52				
avg		11,857,731.33				

From the table above, it can be seen that

$$L_{calculated} = \max\{|F(Z_i) - S(Z_i)|\} = 0.2194$$

$$L_{table} = L_{\alpha(n)} = L_{0.05(12)} = 0.242$$

It is obtained that $L_{calculated} < L_{table}$, thus H_0 is accepted.

Therefore, the Petro Urea Fertilizer data comes from a normally distributed population.

By conducting the normality test on 15 types of fertilizer, it is found that all 15 types meet the assumption of normal distribution. Thus, inventory control calculations can be performed using the EOQ and POQ methods.

3.4. Economic Order Quantity Method (EOQ)

The EOQ method serves to determine the optimal order quantity so that total inventory costs can be minimized. The EOQ calculation is performed as follows:

$$EOQ = \sqrt{\frac{2DS}{H}}$$

Once the optimal EOQ is obtained, the next step is to calculate the order frequency within one year. The order frequency calculation is as follows:

$$F = \frac{D}{EOQ}$$

Based on the two formulas above, the economic order quantity and the order frequency for each type of fertilizer, expressed in kilograms, are determined.

Table 4. Calculation of Economic Order Quantity (EOQ)

No	Fertilizer Name	Total Sales (kg)	Ordering Cost (Rp.)	Holding Cost per Kg (Rp.)	EOQ (Kg)	Order Frequency /Year
1	Urea Petro	142,292,776	1,000,000	0.97	17,128,548.30	8.3
2	Urea Nitrea	92,612,896	1,000,000	1.012	13,528,837.30	6.8
3	Urea PIM	63,128,463	1,000,000	0.9	11,844,216.87	5.3
4	NPK Pusri	40,971,400	1,000,000	1.315	7,893,916.41	5.2
5	SP-26 Petro	36,740,508	1,000,000	1.45	7,118,747.27	5.2
6	Urea Pusri Prill	60,892,381	1,000,000	0.756	12,692,161.16	4.8
7	Urea Daun Buah	46,272,521	1,000,000	0.775	10,927,623.59	4.2
8	NPK pelangi	22,156,707	1,000,000	0.826	7,324,493.22	3.0
9	NPK Majemuk Kujang	17,950,634	1,000,000	0.8725	6,414,638.35	2.8
10	NPK Kebomas	28,483,267	1,000,000	0.5376	10,293,907.66	2.8
11	Phosgreen	21,794,532	1,000,000	0.42	10,187,418.01	2.1
12	ZA Plus Petro	6,557,238	1,000,000	0.64	4,526,739.31	1.4
13	ZA Kujang	3199468	1,000,000	0.545	3,426,538.63	0.9
14	ZA Petro	3199468	1,000,000	0.54	3,442,365.68	0.9
15	SP-36 Petro	135,135	1,000,000	0.98	525,153.04	0.3

3.5. Period Order Quantity Method (POQ)

The POQ method shares similarities with EOQ, but its difference lies in converting the order quantity into an ordering period, resulting in consistent intervals. The POQ calculation is performed as follows:

$$POQ = \sqrt{\frac{2S}{DH}}$$

After obtaining the POQ result, which represents the ordering interval within one year, the next step is to calculate the order frequency and the optimal order quantity for that year. The calculations are as follows:

$$Q = D \times POQ$$

Based on the two formulas above, the economic order quantity and the order frequency for each type of fertilizer, expressed in kilograms, are determined.

Table 5 shows that the POQ order quantity Q is identical to the EOQ in Table 4 for every fertilizer; the ordering interval ranges from 0.12 years (about 44 days) for Urea Petro to 3.89 years for SP-36 Petro. For the items with a POQ longer than one year, the order quantity exceeds the annual demand, which conflicts with the storage risk from humidity and temperature reported by the company.

Table 5. Calculation of Periodic Order Quantity (POQ)

No	Fertilizer Name	Total Sales (kg)	Ordering Cost (Rp.)	Holding Cost per Kg (Rp.)	POQ	Order Frequency /Year	Q
1	Urea Petro	142,292,776	1,000,000	0.97	0.12	8.3	17,128,548.30
2	Urea Nitrea	92,612,896	1,000,000	1.012	0.15	6.8	13,528,837.30
3	Urea PIM	63,128,463	1,000,000	0.9	0.19	5.3	11,844,216.87
4	NPK Pusri	40,971,400	1,000,000	1.315	0.19	5.2	7,893,916.41
5	SP-26 Petro	36,740,508	1,000,000	1.45	0.19	5.2	7,118,747.27
6	Urea Pusri Prill	60,892,381	1,000,000	0.756	0.21	4.8	12,692,161.16
7	Urea Daun Buah	46,272,521	1,000,000	0.775	0.24	4.2	10,927,623.59
8	NPK pelangi	22,156,707	1,000,000	0.826	0.33	3.0	7,324,493.22
9	NPK Majemuk Kujang	17,950,634	1,000,000	0.8725	0.36	2.8	6,414,638.35
10	NPK Kebomas	28,483,267	1,000,000	0.5376	0.36	2.8	10,293,907.66
11	Phosgreen	21,794,532	1,000,000	0.42	0.47	2.1	10,187,418.01
12	ZA Plus Petro	6,557,238	1,000,000	0.64	0.69	1.4	4,526,739.31
13	ZA Kujang	3199468	1,000,000	0.545	1.07	0.9	3,426,538.63
14	ZA Petro	3199468	1,000,000	0.54	1.08	0.9	3,442,365.68
15	SP-36 Petro	135,135	1,000,000	0.98	3.89	0.3	525,153.04

3.6. Lead Time

The time elapsed from placing an order to receiving the goods is called lead time. At PT Pupuk Indonesia, the lead time for fertilizer orders is four days.

3.7. Safety Stock

Safety stock is held as a reserve to cushion against demand that exceeds the company's forecasts. Its calculation is as follows:

$$SS = SD \times Z$$

PT Pupuk Indonesia sets a 5% stockout probability, from the normal distribution table, this corresponds to a safety factor (Z) of 1,65.

3.8. Reorder Point

Reorder points are scheduled before stock is depleted so that goods arrive on time. The calculation to determine the inventory level at which a reorder should be placed is as follows:

$$ROP = SS + (LT \times d)$$

Based on the calculation results using the formula above, the reorder point for each type of fertilizer is obtained as follows:

Table 6. Calculation of Reorder Point

No	Fertilizer Name	Total Sales (kg)	Lead Time (Day)	Safety Stock (Kg)	Reorder Point (Kg)
1	Urea Petro	142,292,776	4	5,074,344.86	6,629,457.16
2	Urea Nitrea	92,612,896	4	3,694,257.02	4,706,419.82
3	Urea PIM	63,128,463	4	2,821,518.65	3,511,447.20
4	NPK Pusri	40,971,400	4	3,872,842.53	4,320,617.39
5	SP-26 Petro	36,740,508	4	3,789,821.11	4,191,356.72
6	Urea Pusri Prill	60,892,381	4	1,023,923.55	1,689,414.06
7	Urea Daun Buah	46,272,521	4	3,163,268.96	3,668,979.57
8	NPK pelangi	22,156,707	4	1,821,670.52	2,063,820.32
9	NPK Majemuk Kujang	17,950,634	4	1,948,467.05	2,144,648.84
10	NPK Kebomas	28,483,267	4	2,497,108.75	2,808,401.28
11	Phosgreen	21,794,532	4	2,045,935.37	2,284,126.98
12	ZA Plus Petro	6,557,238	4	377,320.14	448,983.94
13	ZA Kujang	3199468	4	207,723.33	242,690.20
14	ZA Petro	3199468	4	358,720.87	393,687.74
15	SP-36 Petro	135,135	4	24,229.49	25,706.38

3.9. Calculation of Total Inventory Cost

3.9.1. TIC EOQ

The calculation of the Total Inventory Cost (TIC) using the EOQ method is the sum of the total ordering costs and the total holding costs. The formula for calculating the Total Inventory Cost (TIC) is as follows:

$$TIC\ EOQ = \frac{D}{Q}S + \frac{Q}{2}H$$

Table 7. Calculation of Total Inventory Cost Using the EOQ Method

No	Fertilizer Name	Total Sales (kg)	Ordering Cost (Rp.)	Holding Cost per Kg (Rp.)	EOQ (Kg)	TIC With EOQ (Rp.)
1	Urea Petro	142,292,776	1,000,000	0.97	17,128,548.30	16,614,691.86
2	Urea Nitrea	92,612,896	1,000,000	1.012	13,528,837.30	13,691,183.35
3	Urea PIM	63,128,463	1,000,000	0.9	11,844,216.87	10,659,795.19
4	NPK Pusri	40,971,400	1,000,000	1.315	7,893,916.41	10,380,500.08
5	SP-26 Petro	36,740,508	1,000,000	1.45	7,118,747.27	10,322,183.55
6	Urea Pusri Prill	60,892,381	1,000,000	0.756	12,692,161.16	9,595,273.84
7	Urea Daun Buah	46,272,521	1,000,000	0.775	10,927,623.59	8,468,908.29
8	NPK pelangi	22,156,707	1,000,000	0.826	7,324,493.22	6,050,031.40
9	NPK Majemuk Kujang	17,950,634	1,000,000	0.8725	6,414,638.35	5,596,771.96
10	NPK Kebomas	28,483,267	1,000,000	0.5376	10,293,907.66	5,534,004.76
11	Phosgreen	21,794,532	1,000,000	0.42	10,187,418.01	4,278,715.56
12	ZA Plus Petro	6,557,238	1,000,000	0.64	4,526,739.31	2,897,113.16
13	ZA Kujang	3199468	1,000,000	0.545	3,426,538.63	1,867,463.55
14	ZA Petro	3199468	1,000,000	0.54	3,442,365.68	1,858,877.47
15	SP-36 Petro	135,135	1,000,000	0.98	525,153.04	514,649.98
					Total	108,330,163.98

Based on Table 7, the total inventory cost of the 15 types of fertilizer using the EOQ method is Rp108,330,164.

3.9.2. TIC POQ

The calculation of total inventory cost (TIC) using the POQ method incorporates safety stock.

$$TIC_{POQ} = \frac{S}{POQ} + \left(\frac{Q}{2} + SS\right) \times H$$

Based on the results of the calculation using the above formula, the total inventory cost for each type of fertilizer, expressed in rupiah, is as follows:

Table 8. Calculation of Total Inventory Cost Using the POQ Method

No	Fertilizer Name	Total Sales (kg)	Ordering Cost (Rp.)	Holding Cost per Kg (Rp.)	POQ (Frequency)	Safety Stock (Kg)	TIC with POQ (Rp.)
1	Urea Petro	142,292,776	1,000,000	0.97	8.3	5,074,344.86	21,536,806.37
2	Urea Nitrea	92,612,896	1,000,000	1.012	6.8	3,694,257.02	17,429,771.46
3	Urea PIM	63,128,463	1,000,000	0.9	5.3	2,821,518.65	13,199,161.97
4	NPK Pusri	40,971,400	1,000,000	1.315	5.2	3,872,842.53	15,473,288.01
5	SP-26 Petro	36,740,508	1,000,000	1.45	5.2	3,789,821.11	15,817,424.16
6	Urea Pusri Prill	60,892,381	1,000,000	0.756	4.8	1,023,923.55	10,369,360.05
7	Urea Daun Buah	46,272,521	1,000,000	0.775	4.2	3,163,268.96	10,920,441.73
8	NPK pelangi	22,156,707	1,000,000	0.826	3.0	1,821,670.52	7,554,731.25
9	NPK Majemuk Kuja	17,950,634	1,000,000	0.8725	2.8	1,948,467.05	7,296,809.46
10	NPK Kebomas	28,483,267	1,000,000	0.5376	2.8	2,497,108.75	6,876,450.42
11	Phosgreen	21,794,532	1,000,000	0.42	2.1	2,045,935.37	5,138,008.42
12	ZA Plus Petro	6,557,238	1,000,000	0.64	1.4	377,320.14	3,138,598.04
13	ZA Kujang	3199468	1,000,000	0.545	0.9	207,723.33	1,980,672.77
14	ZA Petro	3199468	1,000,000	0.54	0.9	358,720.87	2,052,586.74
15	SP-36 Petro	135,135	1,000,000	0.98	0.3	24,229.49	538,394.88
Total							139,322,505.71

Based on Table 8, the total inventory cost of the 15 types of fertilizer using the POQ method is Rp139,322,506.

3.9.3. Company Total Inventory Cost (TIC)

The company is assumed to order each fertilizer four times a year, as in the original Table 9, with an ordering cost of Rp1,000,000 per order, so that the order quantity is D/4 and the total inventory cost follows Equation (7) with $Q = D/4$, that is $TIC = 4 \times S + (D/8) \times H$.

Table 9. Calculation of Total Inventory Cost According to the Company

No	Fertilizer name	Annual sales (kg)	Order quantity D/4 (kg)	Ordering cost (Rp)	Holding cost (Rp)	TIC (Rp)
1	Urea Petro	142,292,776	35,573,194	4,000,000	17,252,999	21,252,999
2	Urea Nitrea	92,612,896	23,153,224	4,000,000	11,715,531	15,715,531
3	Urea PIM	63,128,463	15,782,116	4,000,000	7,101,952	11,101,952
4	NPK Pusri	40,971,400	10,242,850	4,000,000	6,734,674	10,734,674
5	SP-26 Petro	36,740,508	9,185,127	4,000,000	6,659,217	10,659,217
6	Urea Pusri Prill	60,892,381	15,223,095	4,000,000	5,754,330	9,754,330
7	Urea Daun Buah	46,272,521	11,568,130	4,000,000	4,482,650	8,482,650
8	NPK Pelangi	22,156,707	5,539,177	4,000,000	2,287,680	6,287,680
9	NPK Majemuk Kujang	17,950,634	4,487,658	4,000,000	1,957,741	5,957,741
10	NPK Kebomas	28,483,267	7,120,817	4,000,000	1,914,076	5,914,076
11	Phosgreen	21,794,532	5,448,633	4,000,000	1,144,213	5,144,213
12	ZA Plus Petro	6,557,238	1,639,310	4,000,000	524,579	4,524,579
13	ZA Kujang	3,199,468	799,867	4,000,000	217,964	4,217,964
14	ZA Petro	3,199,468	799,867	4,000,000	215,964	4,215,964
15	SP-36 Petro	135,135	33,784	4,000,000	16,554	4,016,554
Total		586,387,394		60,000,000	67,980,124	127,980,124

Based on Table 9, the company's total inventory cost of the 15 types of fertilizer is Rp127,980,124.

The comparison between the company's total inventory cost and the costs of the EOQ and POQ methods is shown in Table 10.

Table 10. Comparison of Total Inventory Cost According to the Company, EOQ, and POQ

No	Fertilizer name	TIC company (Rp)	TIC EOQ (Rp)	TIC POQ (Rp)	Company – EOQ (Rp)	Company – POQ (Rp)
1	Urea Petro	21,252,999	16,614,692	21,536,806	4,638,307	-283,807
2	Urea Nitrea	15,715,531	13,691,183	17,429,771	2,024,348	-1,714,240
3	Urea PIM	11,101,952	10,659,795	13,199,162	442,157	-2,097,210
4	NPK Pusri	10,734,674	10,380,500	15,473,288	354,174	-4,738,614
5	SP-26 Petro	10,659,217	10,322,184	15,817,424	337,034	-5,158,207
6	Urea Pusri Prill	9,754,330	9,595,274	10,369,360	159,056	-615,030
7	Urea Daun Buah	8,482,650	8,468,908	10,920,442	13,742	-2,437,791
8	NPK Pelangi	6,287,680	6,050,031	7,554,731	237,649	-1,267,051
9	NPK Majemuk Kujang	5,957,741	5,596,772	7,296,809	360,969	-1,339,068
10	NPK Kebomas	5,914,076	5,534,005	6,876,450	380,071	-962,375
11	Phosgreen	5,144,213	4,278,716	5,138,008	865,497	6,205
12	ZA Plus Petro	4,524,579	2,897,113	3,138,598	1,627,466	1,385,981
13	ZA Kujang	4,217,964	1,867,464	1,980,673	2,350,500	2,237,291
14	ZA Petro	4,215,964	1,858,877	2,052,587	2,357,087	2,163,377
15	SP-36 Petro	4,016,554	514,650	538,395	3,501,904	3,478,159
Total		127,980,124	108,330,164	139,322,506	19,649,960	-11,342,381

Based on Table 10, the EOQ method reduces the company's total inventory cost by Rp19,649,960, or 15.35%, whereas the POQ method with safety stock is Rp11,342,382 (8.86%) more expensive than the company's policy, because the safety stock is included in the POQ cost and not in the company cost.

Table 11. Comparison of Total Inventory Cost According to the Company, EOQ, and POQ for Group A

No	Fertilizer name	TIC company (Rp)	TIC EOQ (Rp)	TIC POQ (Rp)	Company – EOQ (Rp)	Company – POQ (Rp)
1	Urea Petro	21,252,999	16,614,692	21,536,806	4,638,307	-283,807
2	Urea Nitrea	15,715,531	13,691,183	17,429,771	2,024,348	-1,714,240
3	Urea PIM	11,101,952	10,659,795	13,199,162	442,157	-2,097,210
4	NPK Pusri	10,734,674	10,380,500	15,473,288	354,174	-4,738,614
5	SP-26 Petro	10,659,217	10,322,184	15,817,424	337,034	-5,158,207
Total		69,464,373	61,668,354	83,456,452	7,796,019	-13,992,078

Based on Table 11, for the five Group A fertilizers the EOQ method reduces the total inventory cost from Rp69,464,373 to Rp61,668,354, a saving of Rp7,796,019 or 11.22%, whereas the POQ method costs Rp13,992,079 (20.14%) more than the company's policy.

3.10. Discussion

The EOQ and POQ methods give the same lot size (Tables 4 and 5), and the difference in their total costs, Rp30,992,342 for the 15 fertilizers and Rp21,788,098 for Group A, is exactly the holding cost of the safety stock, which is included in the POQ cost and not in the EOQ cost. The higher cost of POQ therefore does not show that EOQ is a better method; it shows the cost of holding safety stock. If the safety stock is included in the cost of both policies, or in the company's cost as well, the EOQ lot size saves the same amount, Rp19,649,960 for the 15 fertilizers, which is 12.36% of the company's cost with the same safety stock (Rp158,972,466), and Rp7,796,019 for Group A, which is 8.54%. The saving of the lot size is thus between 12.36% and 15.35% for the 15 fertilizers and between 8.54% and 11.22% for Group A, depending on whether safety stock is counted.

The savings are small compared with the value of the goods (Rp5.44 trillion), because the holding cost is set at only 0.01% of the annual price, that is Rp0.42 to Rp1.45 per kg per year. The result is very sensitive to this assumption: if the holding cost rate were ten times higher (0.1% of the price), the EOQ policy would cost Rp342,570,057 against Rp739,801,244 for ordering four times a year, a saving of 53.69%. The holding cost rate must therefore be validated with the actual storage, capital, and damage costs of the warehouses before the savings are used in planning. In addition, the safety stock was calculated with the standard deviation of monthly demand for a lead time of four days; scaling it to the lead time (a factor of about 0.37) would reduce the safety stock and its cost by about 63%.

The finding that the EOQ policy reduces the cost relative to the current ordering agrees with Bisri and Andesta (2023), Rizky et al. (2017), Pramesti (2023), and Watanabe et al. (2023), who also found that EOQ lowers the total cost compared with the existing policy (34% for cleaning supplies in Thailand and 70.12% for medicines). The reduction found here (15.4%) is smaller than in these studies. Bisri and Andesta (2023) and Rizky et al. (2017) ranked EOQ above POQ by total cost; in this data set the ranking comes entirely from the treatment of safety stock, which suggests that such rankings should be checked for the same effect. Watanabe et al. (2023) found that only 6 of the 16 Group A items could use the EOQ because of the minimum purchase quantities of suppliers, which is a constraint that should also be checked for the five Group A fertilizers.

The novelty of the findings is therefore that, for 15 fertilizer types, EOQ and POQ are equivalent in lot size, that the saving depends on the safety stock and above all on the holding cost rate, and that the ordering interval of the slow-

moving items exceeds one year, which is not feasible with the storage risks reported by the company. These findings lead to the following recommendations. (1) Adopt the EOQ order quantities for the five Group A fertilizers (for example 17.13 million kg and 8.3 orders per year for Urea Petro) together with the reorder points of Table 6, which gives the same lot sizes as the POQ for periodic ordering. (2) Apply safety stock consistently in the cost of every policy that is compared, and scale it to the lead time. (3) Validate the holding cost rate and the ordering cost with warehouse and finance data, and check the minimum order quantities of suppliers. (4) Cap the lot size of the slow-moving items (ZA Kujang, ZA Petro, and SP-36 Petro) so that the stock is not held for more than a year. (5) Improve the recording of stock so that actual orders and stock levels can be used to update the model.

Several limitations should be noted. Only one year of data and a single order cost were used, the company's policy is assumed to be four orders per year for all fertilizers, the demand is treated as constant in the EOQ although it varies by month, the Lilliefors test used only 12 monthly observations, and the sales of ZA Kujang and ZA Petro are identical (3,199,468 kg), which should be checked. Future research should use several years, the actual order history, and a service-level analysis.

4. Conclusion

The four research questions are answered as follows. First, ABC analysis identified five Group A fertilizers (Urea Petro, Urea Nitrea, Urea PIM, NPK Pusri, and SP-26 Petro) with 72.76% of the investment value. Second, the EOQ gives an order quantity of 17.13 million kg and 8.3 orders per year for Urea Petro, and the other fertilizers are given in Tables 4 to 6 with their safety stocks and reorder points. Third, the EOQ and POQ lot sizes are identical, and the higher cost of the POQ equals the holding cost of its safety stock. Compared with the company's four orders per year, the EOQ lot size reduces the total inventory cost of the 15 fertilizers from Rp127,980,124 to Rp108,330,164 (15.35%) and that of Group A from Rp69,464,373 to Rp61,668,354 (11.22%), and the savings depend strongly on the assumed holding cost rate of 0.01%. Fourth, the company is recommended to adopt the EOQ order quantities with reorder points for the five Group A fertilizers, to apply safety stock consistently, to validate the holding cost rate, and to cap the lot size of slow-moving items.

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