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EOQ-Based Inventory Control of Brown Clay for NPK Fertilizer at PT. Pupuk Kujang

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ABSTRACT

This study investigates the optimization of brown clay inventory management for NPK fertilizer production at PT Pupuk Kujang through the application of the Economic Order Quantity (EOQ) and Total Inventory Cost (TIC) methods. Data analysis of the company's 2023 operations revealed that existing inventory practices led to high ordering frequencies and significant annual costs, totaling Rp230,709,760. By implementing the EOQ approach, the optimal order quantity was determined to be 3,510 tons, reducing the number of orders to seven per year and lowering total inventory costs to Rp3,608,471. Calculation of the reorder point (ROP) further ensured that raw material replenishment could be scheduled proactively, minimizing the risk of production disruptions due to stockouts. The results emphasize the substantial cost savings and operational efficiency improvements gained from adopting the EOQ model. This research contributes practical recommendations for integrating quantitative inventory control methods and highlights the importance of digital inventory systems in supporting supply chain resilience. The findings have broad implications for similar manufacturing industries seeking to enhance competitiveness through data-driven and systematic inventory management.

INTRODUCTION

In the context of modern industrial and business activities, the concept of material inventory is inherently associated with production operations and organizational efficiency. Inventory management is a critical function in manufacturing, directly influencing the planning, operation, and control of materials that underpin the administrative and operational continuity of every organizational unit within a company. Effective inventory control ensures not only the availability of essential materials but also supports the smooth functioning of business processes, minimizes interruptions, and sustains competitive advantage in a dynamic market environment [1], [2].

One prominent challenge faced by manufacturing industries, particularly in the fertilizer sector, is the complexity of managing raw material inventories. For instance, PT Pupuk Kujang Cikampek, a leading producer of NPK fertilizers in Indonesia, relies

heavily on the availability of key raw materials such as brown clay. According to recent company data, the procurement of brown clay reached several hundred tons in 2023, sourced from multiple suppliers to meet the continuous demand for NPK fertilizer production. The absence of an optimal inventory control system can result in either excess inventory, which increases holding costs, or material shortages, which disrupt production schedules and affect customer satisfaction [3].

Given the fluctuating nature of demand and the supply chain uncertainties, particularly as a significant proportion of raw materials are imported, it becomes imperative to implement robust inventory management strategies. One widely recognized approach is the Economic Order Quantity (EOQ) method, which facilitates the determination of optimal order sizes that minimize the total cost associated with ordering and holding inventory [4], [5]. The EOQ model provides a systematic framework for balancing the trade-off between ordering costs and inventory holding costs, enabling companies to maintain sufficient safety stock and accurately determine reorder points (ROP). The accurate application of EOQ principles can thus directly enhance operational efficiency and cost-effectiveness [6].

The significance of implementing EOQ-based inventory control extends beyond mere cost savings. In the case of PT Pupuk Kujang, the ability to anticipate and respond to supply chain disruptions—such as delays in imported materials or sudden surges in demand—is crucial for maintaining uninterrupted production cycles. Recent studies have demonstrated that effective inventory control systems, particularly those employing EOQ techniques, can reduce the risk of material shortages, improve inventory turnover ratios, and support more precise production planning [7], [8]. In addition, the use of advanced data analytics and digital inventory management tools has been shown to further enhance the responsiveness and adaptability of inventory systems, ensuring the timely procurement and utilization of raw materials.

The challenges associated with brown clay inventory management at PT Pupuk Kujang are further exacerbated by the volatile nature of global raw material markets and logistical constraints, necessitating the adoption of proactive inventory policies. Without such policies, production delays, increased operational costs, and compromised product quality may arise, ultimately impacting the company's market position and profitability [9]. Therefore, a comprehensive approach to inventory control—incorporating EOQ calculations, safety stock assessment, and reorder point determination—should be regarded as an essential component of strategic operations management.

Furthermore, the integration of inventory control practices within the broader context of supply chain management ensures that companies can respond to both internal and external pressures. By leveraging EOQ methodologies, PT Pupuk Kujang can optimize its procurement strategies, minimize waste, and enhance the reliability of NPK fertilizer production. As noted in the current literature, continuous evaluation and refinement of inventory control systems are necessary to align with changing market demands and technological advancements [10], [11].

In conclusion, inventory management—specifically the application of EOQ-based approaches—plays a pivotal role in supporting the sustainability and efficiency of fertilizer manufacturing companies. In light of the ongoing challenges posed by fluctuating supply chains and the critical role of raw materials such as brown clay, it is vital for organizations like PT Pupuk Kujang to adopt evidence-based inventory control strategies. This study aims to analyze the implementation of the EOQ method for brown clay inventory at PT Pupuk Kujang and to provide practical recommendations for optimizing material procurement and inventory control.

RESEARCH METHOD

This research employs a quantitative approach to analyze the inventory control system for brown clay used in NPK fertilizer production at PT Pupuk Kujang. The methodology is structured to address the challenges of raw material availability, with a focus on applying the Economic Order Quantity (EOQ) method to optimize procurement and storage costs. The approach is systematic, following the principles of scientific inquiry and best practices in supply chain management [2].

Inventory Definition and System Overview

Inventory, in the context of this study, refers to all materials, components, and finished products maintained by a company to ensure the continuity of production and business operations [6]. The inventory at PT Pupuk Kujang encompasses three main categories: raw materials (such as brown clay), work-in-progress, and finished goods. Raw material inventory, the primary focus of this research, is vital for continuous production flow and efficient order fulfillment [7].

The company employs both periodic and perpetual inventory systems. The periodic system records inventory at the end of each accounting period, while the perpetual system continuously updates inventory levels in real time. These systems form the foundation for assessing current inventory practices and identifying areas for improvement [3].

Research Stages and Data Collection

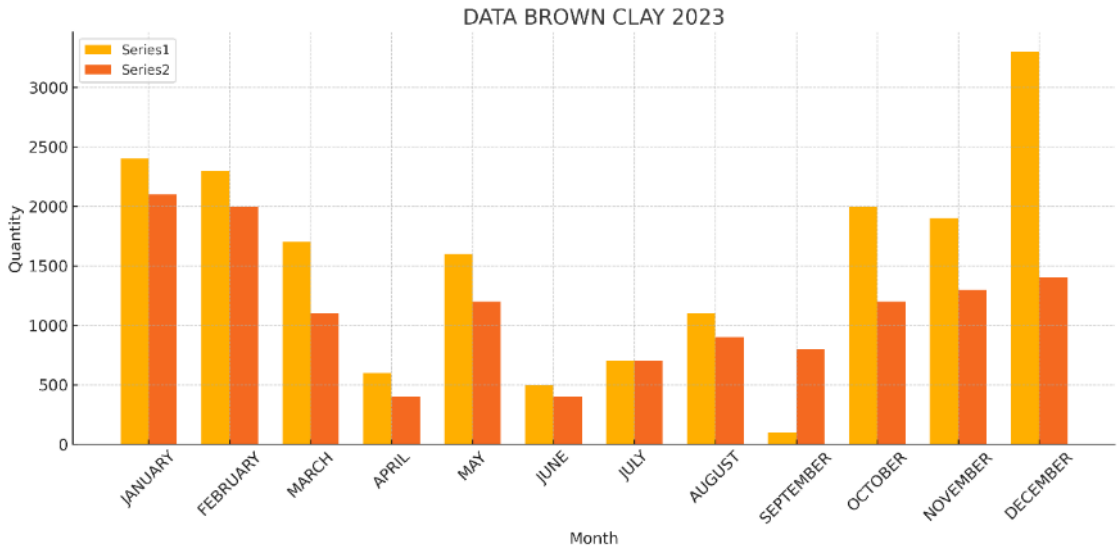

Figure 1. The 2023 Brown Clay Inventory Graph

Data for this research were collected through a combination of company records analysis, direct observations, and structured interviews with inventory management personnel [12]. Quantitative data on monthly brown clay purchases and usage throughout 2023 were analyzed to determine demand patterns and stock fluctuations (see Figure 1 for the 2023 brown clay inventory graph). These data serve as the input for EOQ modeling and subsequent calculations [9].

Economic Order Quantity (EOQ) Application

The EOQ model is utilized to identify the optimal order quantity that minimizes the total cost of inventory, balancing ordering and holding costs [5]. The EOQ formula is expressed as:

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

Where:
D = annual demand (units/year)
S = ordering cost per order
H = holding cost per unit per year

The model also supports the calculation of key inventory metrics such as safety stock, reorder point (ROP), and total inventory cost (TIC). These calculations follow contemporary standards in operational research and industrial management [4].

Reorder Point and Safety Stock Calculation

To prevent stockouts, the reorder point is computed based on average demand and lead time, as follows:

$$ROP = d \times L \quad \text{.....(2)}$$

Where:
d = average daily usage
L = lead time (days)

Safety stock is determined by evaluating variability in demand and lead time, thereby ensuring a buffer against uncertainties in the supply chain [11].

Total Inventory Cost Analysis

Total Inventory Cost (TIC) incorporates both ordering and holding costs:

$$TIC = \left(\frac{D}{Q}\right) S + \left(\frac{Q}{2}\right) H \quad \text{.....(3)}$$

where Q is the order quantity. This comparison of current and EOQ-based practices highlights potential cost savings and efficiency improvements [10].

Research Flowchart

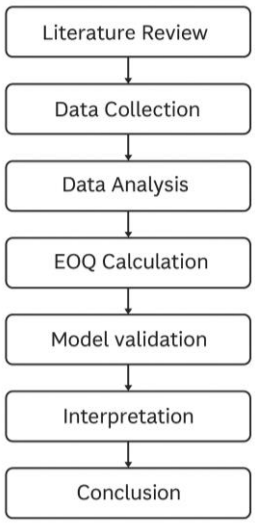

Figure 2. Research Flow

RESULT AND DISCUSSION

Inventory Cost Analysis Using Total Inventory Cost (TIC) Method

The Total Inventory Cost (TIC) method is a fundamental framework for evaluating the overall expenses associated with inventory management in manufacturing enterprises [6], [13]. At PT Pupuk Kujang, the application of the TIC formula—TIC =

(D/Q × S) + (Q/2 × H)—offers a comprehensive view of costs linked to both ordering and storing brown clay, a crucial raw material for NPK fertilizer production.

According to the 2023 operational data, the company executed 594 brown clay orders, resulting in a total procurement of 13,714.36 tons per year. The average monthly inventory reached 6,857.18 tons. With an annual ordering cost of Rp219,429,760 and storage cost of Rp11,280,000, the cumulative expenditure for brown clay inventory in both NPK 1 and 2 warehouses reached Rp230,709,760. This aligns with the findings of Astuti et al. (2021), who emphasized the importance of cost efficiency and strategic procurement in optimizing industrial inventory systems [11].

Table 1. Brown Clay Inventory Data and Cost Analysis (2023)

Month	Frequency	Purchase (ton)	Average	Ordering Cost	Storage Cost	Total Cost
JAN	51	2,466.94	1,233.47	Rp39,471,040	Rp960,000	Rp40,431,040
FEB	43	2,365.68	1,182.84	Rp37,850,880	Rp960,000	Rp38,810,880
MAR	24	1,127.54	563.77	Rp18,040,460	Rp960,000	Rp19,000,460
APR	10	517.18	258.59	Rp8,274,880	Rp960,000	Rp9,234,880
MAY	32	1,564.86	782.43	Rp25,037,760	Rp960,000	Rp25,997,760
JUN	78	679.26	339.63	Rp10,868,160	Rp960,000	Rp11,828,160
JUL	83	976.26	488.13	Rp15,620,160	Rp960,000	Rp16,580,160
AUG	54	1,081.54	540.74	Rp17,303,680	Rp960,000	Rp18,263,680
SEP	27	209.82	104.91	Rp3,357,120	Rp960,000	Rp4,317,120
OCT	0	0	0	Rp0	Rp720,000	Rp720,000
NOV	115	1,947.58	973.79	Rp31,161,280	Rp960,000	Rp32,121,280
DEC	77	777.76	388.88	Rp12,444,160	Rp960,000	Rp13,404,160
Total	**594**	**13,714.36**	**6,857.18**	**Rp219,429,760**	**Rp11,280,000**	**Rp230,709,760**
Average	**49.5**	**1,142.86**	**571.43**	**Rp18,285,813**	**Rp940,000**	**Rp19,225,813**

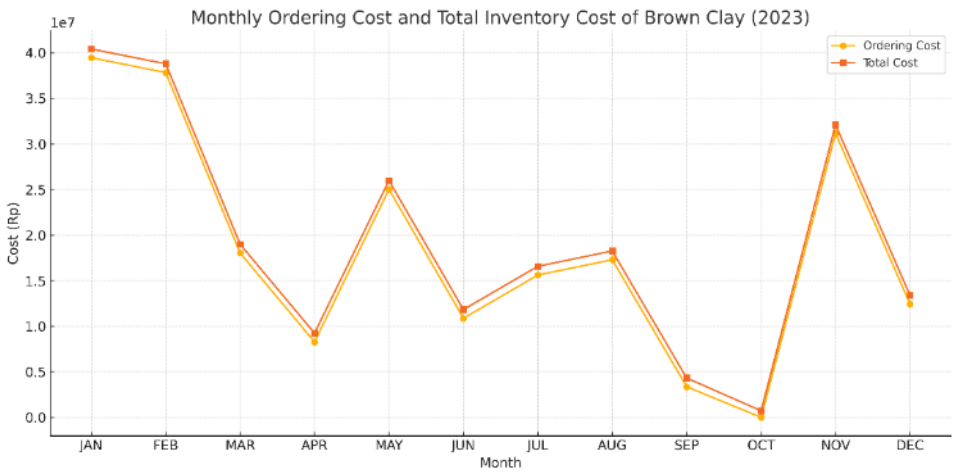

Figure 3. Monthly Ordering and Total Inventory Cost (2023)

Figure 1 illustrates the monthly ordering and total inventory costs for brown clay at PT Pupuk Kujang throughout 2023. The graph shows significant fluctuations in both ordering and total costs across the year, with peaks observed in January, February, May, and November. These months coincide with periods of higher procurement frequencies and increased raw material needs for fertilizer production. Notably, the ordering and total costs are closely aligned, reflecting the proportional relationship between order activities and overall expenditure [14]. The lowest cost values appear in October and September, corresponding with minimal or zero procurement activity. This pattern underscores the influence of demand cycles and operational scheduling on inventory-related expenses. Overall, the data visualization emphasizes the critical need for systematic inventory management, as unregulated order frequencies can result in substantial cost variability and inefficiency [15].

EOQ Method and Cost Efficiency

The EOQ (Economic Order Quantity) model is widely recognized as a standard tool for optimizing inventory management, particularly in industrial settings with significant fluctuations in raw material needs [4], [16]. EOQ calculations in this study use annual demand, ordering cost, and holding cost to determine the most efficient lot size.

From the data, the EOQ for brown clay is calculated as 3,509.87 tons, resulting in an average inventory level of 1,755 tons. The recommended number of orders annually is seven, a substantial reduction compared to the 594 orders under the company's current practice. The annual ordering cost drops significantly from Rp219,429,760 to Rp2,886,736, while annual holding cost is Rp721,735. These results highlight the remarkable efficiency gains achievable by transitioning from a frequent-ordering system to an EOQ-based approach [2], [7].

Table 2. Comparison of Inventory Costs: Current Practice vs. EOQ Method

Parameter	*Current Practice*	*EOQ Method*
Orders per Year	594	7
Total Ordered (tons/year)	13,714.36	13,714.36
Average Inventory (tons)	6,857.18	1,755
Ordering Cost (Rp/year)	219,429,760	2,886,736
Holding Cost (Rp/year)	11,280,000	721,735
Total Cost (Rp/year)	230,709,760	3,608,471

Reorder Point (ROP) and Inventory Responsiveness

The Reorder Point (ROP) is a critical metric for ensuring production continuity, especially in industries where material shortages can disrupt the manufacturing process [3], [8]. Using the calculated EOQ and average demand, the ROP is determined to be 206.46 tons. This value provides a quantitative threshold for triggering new orders,

enhancing the company's ability to respond proactively to inventory depletion and minimizing the risk of stockouts.

Implications for Operations and Future Research

The adoption of EOQ and modern inventory control not only leads to significant cost savings, but also reduces administrative burden, improves cash flow, and enables more strategic supplier negotiations [9], [10]. However, real-world implementation should consider demand variability, supply chain disruptions, and storage constraints. It is recommended that PT Pupuk Kujang integrate digital inventory monitoring and forecasting systems to further enhance efficiency and accuracy.

CONCLUSION

This research has systematically analyzed the inventory management of brown clay—a critical raw material for NPK fertilizer production at PT Pupuk Kujang—using both the Total Inventory Cost (TIC) and Economic Order Quantity (EOQ) methodologies. The findings reveal that the company's current inventory practices, characterized by a high frequency of orders and significant associated costs, result in considerable inefficiencies and elevated operational expenditures.

Application of the EOQ model demonstrates that optimal inventory control can be achieved by reducing the number of orders from 594 to just 7 per year, with an ideal order quantity of approximately 3,510 tons per purchase. This strategy results in a significant reduction in both annual ordering and holding costs, ultimately lowering the total inventory expenditure from Rp230,709,760 to Rp3,608,471 per year. The analysis of the reorder point (ROP) further provides actionable guidance for timely procurement, ensuring uninterrupted production and mitigating the risk of stockouts.

These findings underscore the substantial cost savings, operational efficiencies, and risk mitigation benefits that arise from implementing a systematic EOQ-based inventory approach. The research also highlights the importance of integrating data-driven decision-making and digital inventory systems to further enhance accuracy and responsiveness in raw material management.

In summary, transitioning to an EOQ-based inventory control system is strongly recommended for PT Pupuk Kujang and similar manufacturing enterprises, as it aligns with global best practices and provides a robust foundation for sustainable supply chain management and improved competitiveness in the fertilizer industry.

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