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Inventory Management Analysis Of Engine Lubricant In Transportation Company

Muhammad Yaumal Akbar [1]; Yuanita Handayati [2]
[1,2] **Study Program of Management of Business Administration, Bandung Institute of Technology, Indonesia**
Email: [1] muhammadyaumalakbar@gmail.com ;[2] yuanita@sbm-itb.ac.id

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ABSTRACT

The increasing demand for transportation services in Indonesia has made inventory management for critical maintenance parts, particularly engine lubricants, crucial. This study analyzes engine lubricant inventory management practices at an Indonesian transportation company, which identified recurring stockouts and unmet service levels between 2021 and 2024. The study aims to determine how inventory management analysis can optimize inventory levels, improve service levels, and reduce inventory costs. The research methodology includes ABC analysis, service level analysis, lead time measurement, safety stock calculations, and economic order quantity models. The findings indicate that these methods can improve service levels and reduce inventory costs. The optimal inventory level to increase service levels to 98% is to maintain a safety stock of 5,007 liters, with a reorder point of 16,366 liters. Furthermore, using the Economic Order Quantity (EOQ) method can reduce inventory costs by around 40%.

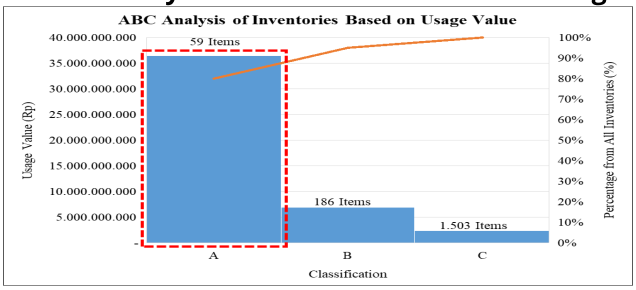
INTRODUCTION

Varghese & Pradhan (2025) mentioned that economic growth will also generates public welfare and causing demand improvements in transportation sector. In line with the improvement of the Indonesian economy of 5,03% in 2024, the transportation sector also showed improvement. According to He et al., (2020), the increment in transport's demand led to the needs of growth in capacity, increasing the needs of fleets to be operated. Critical inventory including engine lubricants that affect safety and reliability need to be managed properly (Zhu et al., 2022). Inventory management, which is an integral part of supply chain management, is needed to manage critical and important inventory (S. Zhang et al., 2021).

One way to ensure inventory is well managed is to provide safety stock (Arasteh, 2022). In addition, it is necessary to determine a reorder point value to prevent stockouts during lead time replenishment in (Nobil et al., 2020). According to Idris et al. (2022), efficient inventory cost is also a parameter for the success of implementing good inventory management, where one of the methods commonly used to reduce total inventory costs is economic order quantity (EOQ).

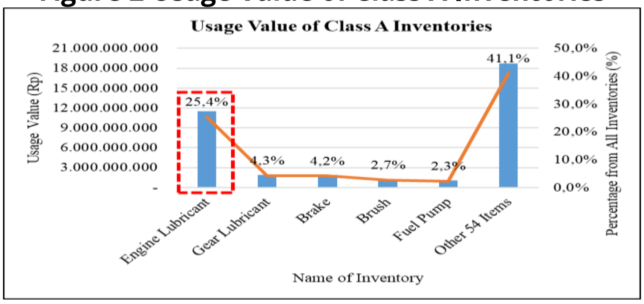
Therefore, this research will discuss inventory management by considering these parameters, which are safety stock, reorder point, and economic order quantity.To identify the problem, first we will classify all inventories within the company at one of the specific operational area which located in Jakarta as a sample. The inventories are classified into ABC class to know which inventory is important or critical. ABC analysis of all inventories based on usage value can be seen from the Figure 1 below.

Figure 1 ABC Analysis of Inventories Based on Usage Value



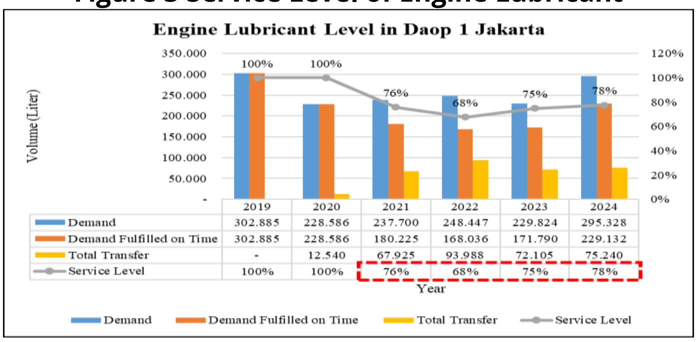
From the bar chart of Figure 1 above, items in category A (80% of the top usage value) consist of 59 items, category B which contributes 15% of the usage value consist of 186 items, and category C with the greatest number of items, 1.503 items, contributes to the bottom 5% of usage value (totaled 100%). If we look further at class A inventories, we can see the names of the inventories and their usage value, which shown in the Figure 2 below.

Figure 2 Usage Value of Class A Inventories



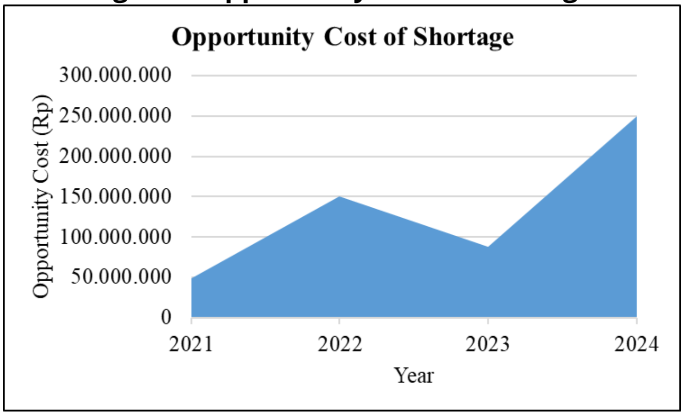
From the graph of Figure 2 above, it is shown that engine lubricant is the inventory with the largest usage value, contributing 25,4% of the total inventories' usage value in year 2024. Then, followed by gear lubricant, brake, brush, fuel pump, and the remaining 54 items (from 59 items in category A) contributed 41,1%. Therefore, in this study, engine lubricant was selected for a more in-depth inventory management analysis. Next, we need to examine the engine lubricant's service level to see whether there is a problem regarding its fulfilment. The service level of engine lubricant is described in the Figure 3 below.

Figure 3 Service Level of Engine Lubricant



Based on Figure 3, even though the service level was fulfilled in year 2019 and 2020, it was not fulfilled from year 2021 to 2024, which was only around 60%-70%. Even though this was also accompanied by gradual recovery of service level from year 2022 to 2024, however the service level still not fulfilled in year 2024. The shortage of engine lubricant is still happened.

Figure 4 Opportunity Cost of Shortage



Due to unmet demand, an opportunity cost arises as outlined in the Figure 4 above. It is the value that could have been obtained if service level had been fully met (Vogt et al., 2013). Opportunity cost will arise when service level is poor (Van Jaarsveld et al., 2013). The magnitude of this opportunity cost depends on the duration of the stockout period, which accumulated stockouts will increase as demand goes unmet over time. The longer the weekly stockout period, the greater the potential opportunity cost (Frederick et al., 2023).

There are risks if engine lubricant having a shortage (Buèinskas et al., 2004). For instances, potential downtime operation off fleets, breakdown of components, reputational damage because of delay & cancellation of trips, and potential revenue loss in the future due to bad service & losing customers. Based on that explanation above, inventory management is very important to solve these problems (Grützner et al., 2025). Safety stock needs to be provided to avoid stockouts and reorder point also need to be set so that the reorder policy can be appropriate and avoid shortages during replenishment during the lead time (Arasteh (2022) & Nobil et al., (2020)). Apart from that, it is also necessary to see whether there is potential inventory cost efficiency that can be done using economic order quantity (EOQ) method (Idris et al., 2022). Hence, this research will analyze further regarding the inventory management of engine lubricant within selected sample area of Jakarta with the aim of optimizing its inventory levels, increasing the service level, and calculating potential cost efficiencies by considering safety stock, reorder point, and economic order quantity (EOQ).

The purpose of this study was to answer the following questions.

1. How much the optimal inventory level by considering safety stock and reorder point of engine lubricant to provide adequate service level?
2. Can economic order quantity (EOQ) model optimize inventory cost of engine lubricant?

The objectives of this study are described below.

1. To obtain the optimal inventory level of engine lubricant and better service level in the future by considering safety stock and reorder point.
2. To obtain inventory cost efficiency by comparing the economic order quantity (EOQ) model and current implementation practice.

LITERATURE REVIEW

Inventory Management

Inventory management entails controlling the quantities of raw materials, work-in-process, finished goods, and spare parts (including lubricants) to align with operational and strategic objectives. According to Grützner et al. (2025), inventory management involves decisions like when to reorder or adjust safety stock to meet service levels. Inventory is managed using variety of scientific and operational methodologies, such as ABC analysis, safety stock analysis, economic order quantity (EOQ) model, etc.The influence of effective inventory management is clear, it reduces costs, enhances service levels, and improves supply chain resilience. Grützner et al. (2025) state that inventory management supports critical goals like profitability, resilience, and sustainability. According to MacAs et al. (2021), the function of inventory management is to maintain raw materials, work-in-progress, and finished goods at the optimum service level while keeping minimum cost. In the transportation sector, Wang et al. (2025) delves that by optimizing inventory management for critical inventories will enhance operational reliability and reduced inventory management cost.

Service Level

According to Radasanu (2016), the measurement of the service level is important in the inventory management because it can affect the relationship with its customer. Service level can be defined as the expected probability of not hitting a stockout during the next replenishment cycle. Stockout is a risk for the company that can reduce customer's satisfaction in the long-run. Company must take efforts to improve service level as a goal, yet it must be monitored, and should be a continuous improvement process, even though calculating service level also has challenges in practical, such as demand variability and lead time fluctuation.Based on the study of Chabot et al. (2018) in the transportation sector, greater service level will reduce breakdowns and stockout risks. With better service level, it will improve the utilization of the company's transportation fleet. It also allows more predictable operation scheduling of the fleet. According to Radasanu (2016), important inventory generally uses 96% to 98% service level.

$$Service\ Level\ (SL) = \frac{Annual\ Demand}{Demand\ Fulfilled\ On\ Time}$$

In determining the level of service level used in this thesis, several of the following criteria below were considered.

- Characteristic of the product
  Lubricant is a critical inventory for locomotive operations. If lubricant stockout occurs, fleets cannot operate, causing delays or penalties. This indicates high critically characteristic inventory which requires high service level.
- Substitutability
  If lubricant has no substitute or specific to fleet engine type, then stockout will increase risks. This justifies the need of high service level.
- The company needs
  If the company has a service level policy, it could be a consideration. But if the company does not explicitly state a required service level, operational information indicate that engine lubricant shortages are risky for fleet operations. It supports the selection of high service level.
- General industry
  Important or critical inventory generally uses 96% to 98% service level (Radasanu, 2016). From the consideration of the previous criteria, it is stated that engine lubricant is a critical inventory that requires a high service level. Thus, the highest number from the range of 96% to 98% deemed suitable for use.

Hence from this consideration, the research uses 98% service level. It is considered a suitable, prudent, and better service level. This service level value will be used for further calculations.

Lead Time

Lead time is the period between placing an order and receiving it (Ben-Ammar et al., 2022). It is the duration between when an order is placed to the supplier and when the goods is delivered to the requesting company (de Oliveira et al., 2021). According to (Mohammed & Mandal, 2024), lead time consist of pre-processing, processing, and post-processing time. Lead times are influenced by efficiency and reliability of suppliers. Companies that have strong partnership with their suppliers can often negotiate better lead times, know early if there are potential delays, and manage issues before it they escalate. According to Wang et al. (2025), lead time in transportation sector is one of the key parameters in the inventory management. The study shows that increasing lead time results in higher order points, higher quantities, and increased total cost. It demonstrates the critical impact of lead time calculation on inventory performance.

$$Lead\ Time\ (LT) = Pre\ processing\ time + Processing\ time + Post\ processing\ time$$

Safety Stock

According to Arasteh (2022), organizations hold safety stock to reduce the effect of the losses caused by uncertainty, while they also want to increase customer satisfaction. Safety stock is held to raise the response rate for demand. The response rate is the proportion of demands that have been fulfilled on time. Demand variation plays a big role in setting safety stocks, considering the reality that demand is hard to forecast accurately (Kırmızı et al., 2024).

In transportation sector, regarding fleet maintenance, safety stock refers to keeping an extra buffer of spare parts or lubricants beyond the forecasted demand (Idris et al., 2022). Safety stock is a preventive buffer of spare parts to guarantee continuous operation and safety, but it must be carefully managed because excess inventory will increase costs. The purpose of safety stock is to avoid shortages that could cause service interruptions or safety risks, since transportation fleets must operate with high reliability, availability, and safety. To calculate the safety stock, we first calculate the standard deviation using formula below.

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(Xi - \bar{X})}{n-1}}$$

Where:

σ = standard deviation of demand (unit),

X_i = demand in period i (units),

$\bar{X}$ = average demand (units),

n = period (time unit).

The formula of safety stock calculation is shown below.

$$Safety\ Stock\ (SS) = Z\ x\ \sqrt{LT}\ x\ \sigma$$

Where:

SS = safety stock (unit),

Z = Z-score corresponding to the desired service level (number),

LT = lead time (number),

σ = standard deviation of demand (unit),

Reorder Point

According to Nobil et al. (2020), reorder point (ROP) is an order that is placed when inventory drops to certain level. It is important parameter in inventory management. By knowing ROP, companies can decide an appropriate time of ordering inventories to avoid overstocking, shortage, or stockout. ROP helps managers and researchers to design their inventory management system to bring efficiency (Nobil et al., 2020).

According to Lertsumruai (2023), in the context of transportation sector, ROP ensures that critical spare parts especially safety-sensitive, is available before stockout occurs. One way to increase efficiency in fleet maintenance is to calculate ROP so that lubricant is sufficient for maintenance. Lertsumruai (2023) apply inventory management alongside ROP to determine the optimal time and quantity for ordering spare parts using spreadsheet system. The formula of reorder point is shown below.

$$ROP = SS + (LT \; x \; \bar{d}$$

Where:

ROP = reorder point (unit),

SS = safety stock (unit),

LT = lead time (time unit),

$\bar{d}$ = average demand (unit).

Holding Cost

According to Azharudin (2024), inventory holding costs, also known as carrying costs, are the expenses associated with storing unsold goods or inventory. It is defined as the expenses of storage cost, finance cost, obsolescence cost, and handling cost (Gurtu, 2021). Inventory is hold at warehouse, which can be rented from other party or wholly owned by the company itself. Depreciation cost is a component within storage cost if the warehouse is wholly owned and rent cost will arise if the warehouse is rented from other. For inventory with high storage cost, it is usually offset by low inventory stock but more frequent replenishment.

Holding cost are particularly important in transportation sector, where inventories must be stocked to avoid service disruptions (Idris et al., 2022). Effective control of inventory holding cost is critical for reducing overall operational costs. According to Gurtu (2021), inventory holding cost consist of some components such as storage cost, cost of finance, cost of obsolescence, and cost of handling. If the holding cost of an inventory is unknown, a calculation can be made to determine its value. According to Gurtu (2021), the formula for calculating inventory holding cost is explained below.

$$H_k = \frac{C_w \, A_i \, I_k}{\delta \, A_w \, S_i \, B_j \, X_k} + P_k I_k (C_f + C_o) + \frac{I_k}{X_k} C_h$$

Where:

H_k = inventory holding cost of SKU k (Rp),

C_w = rent or depreciation cost of warehouse (Rp),

A_i = area of rack or pallet type i (this is the area of the pallet that stored on the ground) (m^2),

I_k = average annual inventory of SKU k (Unit),

δ = area utilization factor where 0 < δ < 1 (Rp),

A_w = area of warehouse (m^2),

S_i = number of shelves in rack or pallet type i (for storage on the ground, N=1) (number),

B_j = number of bins or pallets type j kept on the shelf (number),

X_k = number of SKU in a bin (or in a pallet) where k is an SKU (number),

P_k = unit price of an SKU k (Rp / unit),

C_f = cost of finance (%),

C_o = cost of obsolescence (%),

C_h = cost of handling (Rp),

Ordering Cost

Ordering cost is the total expense incurred each time a purchase order is placed (Alsaedi, 2024). It includes requisition preparation, supplier coordination, invoice processing, and inspection of received goods. According to Majumder (2015), ordering cost also represent the administrative and managerial expenses required to create a purchase or production order. It covers specific tasks such as verifying item quantities and determining the amount to be ordered. Additionally, expenses related to operating and maintaining the system that monitors order transactions are also classified as ordering cost.

Ordering cost plays a crucial role in balancing order frequency and inventory holding cost, ensuring optimal inventory replenishment strategies (Gurtu, 2021). The calculation of inventory ordering cost includes labor cost, overhead cost, and non-labor cost (Prasad et al., 2021). If the ordering cost is unknown, then the calculation can be made. The outline formula to calculate ordering cost is represented below.

$$S = Labor\ cost + Overhead\ cost + Non\ labor\ cost$$

Shortage Cost

Based on the study by Kırmızı et al. (2024), the calculation of shortage cost can be made using parameter that correlated to the industry. In this research, there are important parameters or costs that arise regarding the shortage of engine lubricant within transportation sector. First is additional transportation cost, because lubricant will be needed to be transferred from the other area that have the stock to the area that needed. Second is additional maintenance cost, because shortage of engine lubricants can cause another component's breakdown that need to be maintained or replaced. Third is the reputation cost that arise from the delay or cancelation of the trip. Hence, if the shortage cost within company is unknown, then shortage cost can be calculated using the formula below.

$$Shortage\ Cost = Transportation\ cost + Maintenance\ cost + Reputation\ Cost$$

Transportation cost includes an estimate of the costs that incurred due to the delivery of transfer stock from other operational areas. For instances, cost of renting delivery trucks, cost of fuels, loading and unloading costs, as well as administration or other related cost. During the year of 2024, the selected sample area made several engine lubricant transfers from several other operational areas.

Also, when engine lubricant's shortage occurred, there were potential maintenance or spare part replacement costs, as well as decreased fleets performance due to lack of engine lubricant. Historically in 2024, there was a fleet breakdown due to a lack of lubricant, requiring replacement of other corelated spare part. This resulted in additional maintenance costs and decreased fleet performance.And lastly, the shortage cost component is reputation cost. This is the estimated cost incurred due to trip delays. Although historically in year 2024, trip delays due to lubricant shortages were low number. This cost can be determined by calculating value of time (VOT). According to (Small, 2012), value of time (VOT) is the traveler's willingness to pay for time savings. This means VOT measures how much a traveler is willing to sacrifice to reduce their travel time or how much compensation they require if their travel time increase.

Economic Order Quantity

According to Azharudin (2024), maintain an optimal inventory balance is important to managing cost and meeting customer demand. Economic Order Quantity (EOQ) model is applicable to be used in the firms that face challenges to determine optimal inventory levels. EOQ is a model known for its ability to calculate the most economical quantity of inventory to order that consider demand rate, holding, cost, and ordering cost (Azharudin, 2024). EOQ model aiming to achieve the most efficient inventory level, by determining the optimal quantity of an inventory to be ordered (Tebaldi et al., 2023).This research will analyze the economic order quantity (EOQ) inventory model for engine lubricant. By calculating EOQ and compare it with the current implementation, it can be seen whether there is potential inventory cost efficiency within the company. The formula to calculate EOQ explained below (Azharudin, 2024).

$$Economic\ Order\ Quantity\ (EOQ) = \sqrt{\frac{2\ D\ S}{H}}$$

Where:

D = annual demand (units),

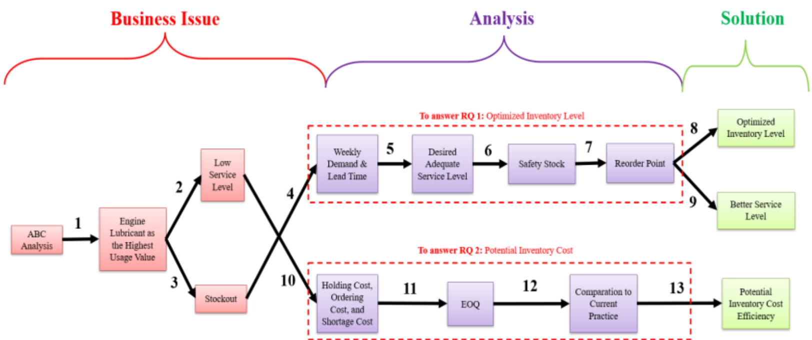
S = ordering cost per order (times),

H = holding cost per unit per year (Rp).

METHODS

In this sub-chapter, will be explained about the conceptual framework and research design that used in this research. Conceptual framework is a systematic structure made up of concepts and propositions that guide thinking, observation, and interpretation of study phenomena (Sale & Carlin, 2025). It helps researchers to prioritize which concepts are most important, clarify meaning relationships, and help shape data collection and analysis. The following Figure 5 represents conceptual framework used in this thesis.

Figure 5 Conceptual Framework

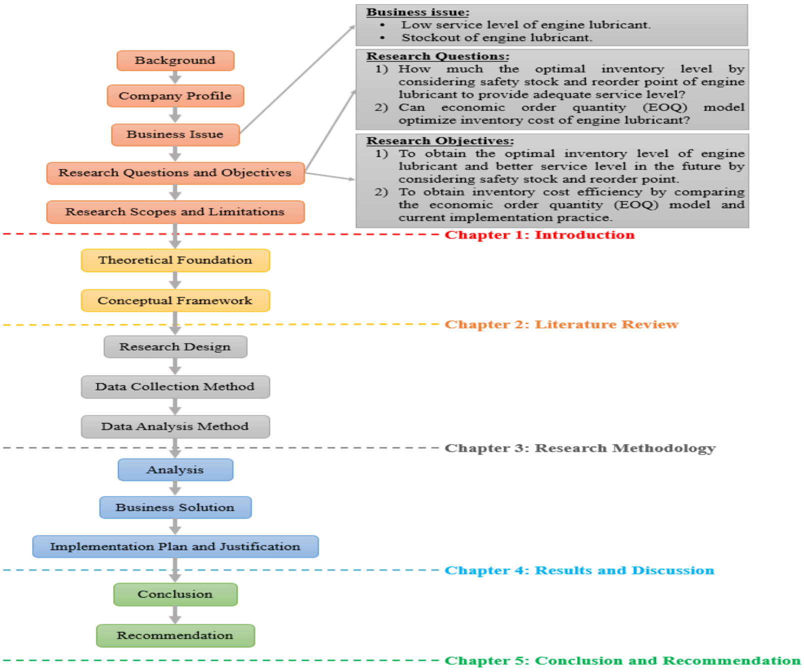


Based on Figure II.1 the explanation on the link between boxes on the conceptual framework described below.

1. This number 1 link process shows that ABC analysis is conducted to gain top of the class A inventory, which resulted that engine lubricant is the inventory with the highest annual usage value.
2. Number 2 link represent that by calculating the service level, resulting that engine lubricant had low service level in selected operational area.
3. Number 3 link represent that by evaluating the demand and total stock of engine lubricant in selected sample area, it experienced stockout in recent years where it can't meet the demand. The low service level and stock become the business issue and included in research questions.
4. Number 4 has entered data analysis stage. Based on the business issue, there are 2 (two) research questions. We branch the framework into two branches to answer each of the research questions. Branch number one, which is link number 4, is to answer the research question number 1 regarding how much the optimal inventory level needed to provide adequate service level by considering safety stock and reorder point. Then first, we need to find and analyse weekly demand data and analyse the lead time for further analysis of optimal inventory level.
5. Number 5 is where adequate or better service level will be determined to become a reference for further data calculations.
6. In number 6, after desired service level determined and lead time is obtained before, now safety stock for inventory buffer can be calculated.
7. Number 7 explain the process about calculating reorder point, where replenishment order is placed when inventory level drop to certain point.
8. In link number 8, safety stock and reorder point is already obtained. Hence the inventory level can be optimized to prevent stockout in the future.
9. In number 9, the previously determined better service level, which is 98%, is used in the calculation of safety stock and reorder point, so hence in the future, shortage could be minimized, while the inventory also optimized.
10. Link number 10 is the second branch to answer research question number 2 regarding potential inventory cost efficiency. In this link, first the data regarding all kind of inventory cost such as holding cost, ordering cost, and shortage cost is calculated.
11. After all inventory cost already calculated, we can now calculate the EOQ, a method for determining the optimal order quantity that potentially could minimizes total inventory costs.
12. Number 12 process will compare the EOQ method with the current practice. Analysis is conducted whether the EOQ method is better than existing.
13. Lastly number 13 represent the solution whether there is a potential inventory efficiency based on the comparation of EOQ method and current implementation method. The feasibility analysis of the business solution is also conducted to know whether the EOQ method can be applicated and safety stock & reorder point can be implemented.

Research design is a structured plan that organizes goals, procedures, rationale, framing, and mindset to guide a study systematically toward achieving its objectives while considering the context of use (Daalhuizen & Cash, 2021). Research design is a blueprint that explains what the research wants to achieve, how it will be carried out, why it is important, and in what context it is. Below Figure 6 depicts the research design of this thesis.

Figure 6 Research Design



According to Mazhar et al. (2021), data collection method defined as systemic ways of gathering information, either first-hand (primary) through tools like observation, interviews, and questionnaires, or from existing records (secondary), to provide reliable evidence for answering research questions and testing hypotheses. It is an approach that researchers use to gather information needed for their study, either directly collecting new data or by using existing sources. Below Table 1 that describes data collection method in this research.

Table 1 Data Collection Method Used in this Research

No.	Term	Concept / Variable	Required Data	Data Source
1	**Business Issue**	ABC Analysis	List of all inventory and its annual usage value of all inventories in year 2024. Then, zoom into A class to know which inventory have highest percentage of issuance value	Secondary
		Low Service Level	Demand and fulfilled demand data	
		Stockout	Stockout data of engine lubricant from year 2019 to 2024 and opportunity cost that arise	
2	**Research Question 1:** How much the optimal inventory level by considering safety stock and reorder point of Diloka to provide adequate service level in Daop 1 Jakarta?	Demand Data	Annual past demand volume of engine lubricant	
		Service Level	Desired service level	
		Lead Time	Time of procurement, from placing an order until receipt it	
		Safety Stock	Demand data, standard deviation of demand, service level, and lead time	
		Reorder Point (ROP)	Demand data, lead time, and safety stock	
3	**Research Question 2:** Can economic order quantity (EOQ) model optimize inventory cost of engine lubricant?	Holding Cost	Unit price, storage cost, cost of capital, handling cost, and other related cost	
		Ordering Cost	Labor cost, overhead cost, and non-labor cost related to procurement	
		Shortage Cost	Additional transportation cost, additional maintenance cost, and reputation cost related to shortage	
		Economic Order Quantity (EOQ)	Demand data, inventory holding cost, ordering cost, and shortage cost	
4	**Business Solution**	Optimized Inventory Level	Safety stock, and reorder point (to answer business issue number 1)	
		Better Service Level	Desired service level (to answer business issue number 1)	
		Potential Inventory Cost Efficiency	Economic Order Quantity (EOQ) calculation (to answer business issue number 1)	

RESULTS

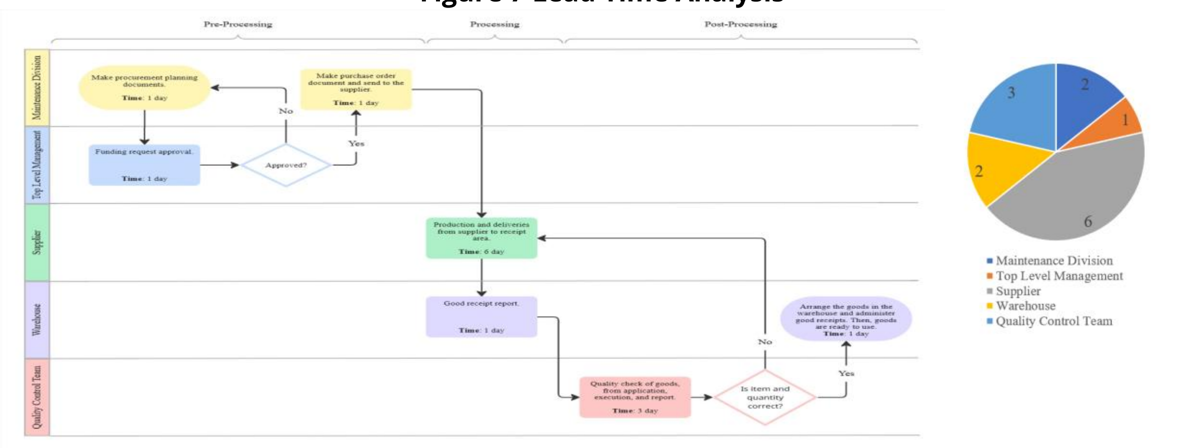
We will divide the results sub-chapter into 2 (two) sections based on the conceptual framework. The first section or point A is optimal inventory level which to answer research question number 1 (one). And second or point B is economic order quantity section to answer research question number 2 (two).

A. Optimal Inventory Level

This section A is a section that focuses to answer the research question number 1 (one). The parameter needed for the first step is to gather historical demand data and the fulfilled demand data. The data is limited to a certain period from the selected sample company within selected operational area. The demand data is obtained from the company, either by observation, interview, etc. The demand data used is in weekly period of year 2024.

From the historical demand data, numerous stockouts occurred during year 2024. From the 295.328 liter of demand, only 229.132 liter were fulfilled on time, resulting a service level of only 78%. The cumulative stockouts that occurred over time were significant. At the end of this research, this existing inventory level will be evaluated and compared with the proposed inventory level by considering the lead time, safety stock, and reorder point, to achieve higher service level. For further analysis, first we need to calculate the lead time of engine lubricant procurement.

Figure 7 Lead Time Analysis



The lead time calculation process begins with pre-processing, which includes the creation of needed procurement documents by the maintenance division. It is followed by documents approval by top level management. If the documents are approved, the maintenance division will proceed to create purchase order and sent it to the supplier, but if there are revisions, it must be revised and resubmit. This pre-processing time takes 3 days. After that, the processing time begins. During this stage, the supplier will produce and deliver the orders. Once the engine lubricant is shipped, the warehouse will receive the goods and make a report. Production and receiving the goods take 7 days.

The final stage is post-processing, which begins with the inspection of the received goods by the quality control team. If the engine lubricant passes the test, the warehouse team can arrange it in the warehouse and prepare a final goods receipt report, but if it fails the test, the supplier is required to fulfil the revisions. The pie chart above shows the processing time for each party. The total lead time for engine lubricant procurement process is 14 days or 2 weeks. That lead time is not considered too long and allows for repeat orders in small quantities with short time intervals but will be discussed in the next sub-chapter after other parameters are evaluated.

Safety Stock

The service level of 98% is already determined from the previous sub-chapter in the literature review because of the inventory's criticality. The z-score from that service level is 2,05. The standard deviation of the demand can be calculated using the formula shown in the literature review section. The standard deviation of engine lubricant is 1.727 liter. Furthermore, the calculation of safety stock is shown below.

$$Safety\ Stock = Z\ x\ \sqrt{LT}\ x\ \sigma = 2{,}05\ x\ \sqrt{2}\ x\ 1.727\ = 5.007$$

From the calculation above, the safety stock of engine lubricant is 5.007 liter per week. The time unit of this thesis uses the weekly period. This safety buffer is designed to protect the system against demand variability during the two weeks lead time while ensuring the service level remain aligned with the target. By holding this amount of safety stock, it can minimize the risk of stockouts, maintain continuity of fleet operation and support reliable maintenance activities. In comparison, currently the company has not implemented formal safety stock policy for its inventory management, so this calculation of buffer stock could help the company in the future to prevent the shortage event.

Reorder Point

After the lead time and safety stock is calculated in the previous section, the reorder point can now be calculated. The calculation regarding reorder point of engine lubricant is shown below.

$$ROP = SS + \left(LT\ x\ \bar{d}\right) = 5.299 +\ (2\ x\ 5.679{,}38) =\ 16.366\ liter$$

From the calculation above, the reorder point of engine lubricant is when the inventory stock reach 16.366 liter. It means that replenishment order must be initiated as soon as the available inventory reaches this threshold. It is to ensure that the incoming order will arrives before stockout occurs during the two weeks lead time. Establishing reorder point is crucial for maintaining operational continuity, as it aligns the timing of procurement activities with both the average demand consumption rate and the required safety stock. By adhering the reorder point, engine lubricant can better stabilize inventory availability, reduce the risk of maintenance delays due to lubricant shortages, and support a more reliable fleet operation.

Economic Order Quantity

This sub-chapter focuses on answering research question number 2 (two) regarding whether there is potential for efficiency in inventory costs by applying economic order quantity (EOQ) method. Before calculate the EOQ, the holding cost, ordering cost, and shortage cost must first be known. Right now, within the company, these costs are currently unavailable and never used before, so the calculations of it are necessary. Next, we will discuss and calculate these inventory costs, which in the end will be used to calculate EOQ.

Holding Cost

The inventory holding cost of engine lubricant is still unknown. Therefore, engine lubricant's holding cost is needed to be determined. From the calculation using the formula in literature review section, the inventory holding cost of engine lubricant is Rp 4.648 per liter per year. It can be converted into percentage of unit price which is 11,8% per liter per year. Because the time unit that used in this research is weeks, it will be easier if the holding cost converted into value per weeks, which is Rp 89,39 per liter per week. This weekly cost parameter will subsequentially serve as an input for determining the economic order quantity (EOQ) later. It will be used for evaluating the cost efficiency of the proposed inventory policy. Then, the next step is to find the ordering cost, which will be explained in the next sub-chapter.

Ordering Cost

Ordering cost of engine lubricant is not directly recorded by the company. Ordering cost in this research is estimated using an activity-based costing approach. Ordering cost includes labor cost, overhead cost, and non-labor cost (Prasad et al., 2021). Labor cost using activity-based costing calculated by first describing all activities in the procurement process and its duration. Then look for the person in charge (PIC) or job level that carries out these activities. Then find the hourly rate for these job levels and multiply it with the duration of the activities. After that, we will get the cost per activity, and if we add up all the costs of all activities, we will get the labor cost in carrying out the engine lubricant order. The result of the labor cost calculation for ordering engine lubricant is Rp 1.971.100 per order.

According to Prasad et al., (2021), besides labor cost, ordering cost's component including overhead cost and non-labor fixed cost. Overhead cost includes utilities such as electricity for computer usage, water usage, and internet usage. It also includes building overhead such as depreciation. This thesis uses the nominal of overhead cost based on the company's policy. Overhead cost that used within the company is Rp 1.287.500.

The last component of ordering cost is non-labor cost, which includes administrative cost and general cost. Administrative cost is office supplies such as papers or stationaries for contract documents. General cost is other related cost (if any) such as travel or communication cost. The non-labor cost is Rp 382.800. Hence, we can sum all the cost which are labor cost, overhead cost, and non-labor cost. It is to determine the ordering cost of engine lubricant. The calculation of ordering cost is showed below.

$$Ordering\ Cost = Rp\ 1.971.100 + Rp\ 1.287.500 + 382.800 = Rp\ 3.641.400\ per\ order$$

From the calculation above, the engine lubricant's ordering cost is Rp 3.641.400. This value represents the total cost incurred each time a replenishment activity is executed, including labor, overhead, and non-labor component such as administrative processing or general operational cost. With the ordering cost parameter already defined, the analysis of EOQ can be proceeded. But before that, the shortage cost calculation of engine lubricant is also needed, which is explained in the next sub-chapter.

Shortage Cost

Shortage cost of engine lubricant is not directly recorded by the company. According to Kırmızı et al. (2024) the assumption of shortage cost can be made according to the industry. So, it is necessary to know what costs will incur if there is a shortage of engine lubricant. Within the company, if there is engine lubricant shortage, then there will be stock transfer from another operational area to fulfil the needs. But, the transfer itself will incur the transportation cost. Furthermore, the shortage of that lubricant also can cause potential damage or breakdown to other components, so that maintenance or component replacement is needed. Besides that, the shortage can cause reputational damage and incur cost, from trip delay and cancellation, which further can incur service recovery cost or potential loss revenue in the future. Hence, we can assume that the company's shortage cost consists of transportation cost, maintenance cost, and reputation cost, as seen in formula in literature review.

Transportation cost includes an estimate of the costs that incurred due to the delivery of transfer stock from other operational areas such as renting trucks, fuel, loading unloading, and administrative cost. Transportation cost calculation in this research considers these parameters. During the year of 2024, the selected operational area of the company made several engine lubricant transfers from several other operational areas. The transportation cost of all these stock transfer amounted Rp 165.562.133.

When engine lubricant shortage occurred, there were additional maintenance and spare part replacement costs, followed by the decrease of fleet performance. Historically in 2024, there was a fleet breakdown due to a lack of lubricant that resulted in additional maintenance costs and decreased locomotive performance amounted Rp 82.268.412. And lastly, the reputation cost, which is the estimated cost incurred due to trip delays. The reputation cost calculated uses the value of time (VOT) theory approach, which according to (Small, 2012), is the traveler's willingness to pay for time savings. It means that VOT measures how much a traveler is willing to sacrifice to fasten their travel time or how much compensation they require if their travel time delayed. Historically in year 2024, trip delays due to lubricant shortages were low and the reputation cost is amounted only Rp 1.314.551.

$$Shortage\ Cost = Rp\ 165.562.133 + Rp\ 82.268.412 + 1.314.551 = Rp\ 249.145.096$$

From the constituent costs before, the engine lubricant's shortage cost can be calculated by summing all those costs which amounted Rp 249.145.096. Then, it is necessary to convert the cost into per liter basis. The total shortage cost will be divided by the value of accumulative shortage volume within year 2024 which is 2.091.822 liter. The accumulative shortage volume of engine lubricant is obtained from the historical data of the company. Hence, the shortage cost per liter of engine lubricant is Rp 119,11 per liter. This parameter is crucial for inventory optimization because it highlights the significant economic burden that stockouts impose on fleet operations.

Economic Order Quantity

Previously we have obtained the value of holding cost and ordering cost from the calculations in the previous sub-chapters. Then at this stage, the economic order quantity (EOQ) calculation can be conducted. The calculation is showed in the formula below.

$$EOQ = \sqrt{\frac{2\ x\ D\ x\ S}{H}} = \sqrt{\frac{2\ x\ 295.328\ x\ 3.641.400}{4.648}} = 21.511\ liter$$

Based on the EOQ calculation, the optimal order quantity for the engine lubricant is 21.511 liter. It will minimize the total inventory costs by balancing holding cost and ordering cost. Therefore, the EOQ value serves as a critical decision parameter for planning replenishment schedules and ensuring cost-efficient inventory management in the transportation company.

DISCUSSION

From all of the previous calculations in the previous section, it can be concluded that the economic order quantity of engine lubricant is at 21.511 liter, while the safety stock (SS) is 5.007 liter and reorder point (ROP) is at 16.366 liter, with the lead time (LT) of 2 weeks. These parameters can be illustrated in a diagram commonly used in inventory management which is called an inventory control chart. The inventory control chart of EOQ, SS, and ROP is showed in the Figure 8 below.

Figure 8 Inventory Control Chart of Engine Lubricant

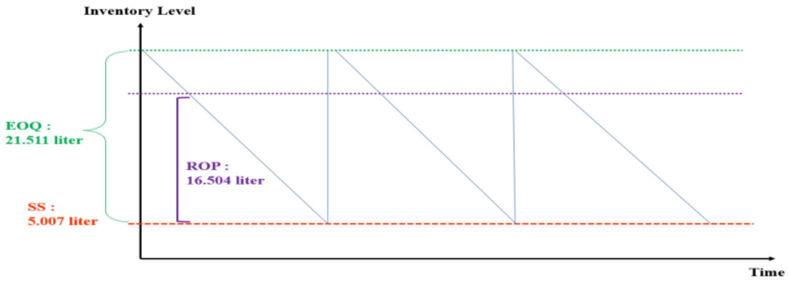


Figure 8 illustrates how the EOQ, safety stock, and reorder point interact within engine lubricant's inventory control system. The chart shows that inventory level gradually decreases over time due to weekly consumption until they reach the reorder point, at which a replenishment must be made. The safety stock provides a protective buffer that prevents stockout during the two weeks lead time. The EOQ level represents the most cost-efficient order quantity, balancing ordering and holding cost. Overall, the diagram clarifies how these three parameters collectively support a more stable and predictable inventory management process.

Comparation of Existing Implementation and Proposed Solution

Based on the previous sub-chapter, various calculation and analyses have been carried out. From the results, several business solutions can be drawn and implemented. The business solution from this research is showed in the Table 2 below.

Table 2 Comparison of Before and After Proposed Solution

No.	Parameter	Before EOQ Implementation	After EOQ Implementation
1	Safety Stock	None	5.007 liter
2	Reorder Point	None	16.366 liter
3	Average Inventory Level	289 liter (shortage occured)	27.046 liter (optimized with no shortage)
4	Service Level	78% (as of year 2024)	98%
5	Yearly Inventory Cost: • Total Holding Cost • Total Ordering Cost • Total Shortage Cost • Total Cost	 Rp1.342.101 Rp25.489.800 Rp249.156.959 Rp275.988.860	 Rp115.646.137 Rp47.338.200 Rp918.815 Rp163.903.151
6	Potential Efficiency in Inventory Cost	Rp112.085.709 (or around 40,6% reduction in percentage)	

By implementing these proposed solutions, the company can achieve more efficient and cost-effective inventory management system within the Jakarta operational area. In line with the conceptual framework from this research, the business solutions offer optimized inventory level to prevent shortage, offer better service level from 78% to 98%, and potential inventory cost efficiency amounted Rp 112.085.709. The research shows that by using EOQ model, combined with appropriate safety stock and reorder points, will ensure the service level is consistently met and help minimize cost.

But, in Table 2 there are trade-offs, including a significant increase in holding cost and a moderate increase in ordering cost. But as advantage, there is also a very sharp decrease in shortage costs. The increase in holding cost is because the existing method didn't carry much inventory and often shortage without safety stock and reorder point, while the new EOQ method added buffer stock or safety stock and reorder point. Conversely, as the holding cost increase, the shortage cost could be reduced significantly because the stockout events is prevented. In total, even though with those trade-offs, the total inventory cost is still reduced.

Feasibility Analysis

Afterwards, to determine whether the business solution is feasible, a feasibility analysis is conducted. This will examine the operational aspects of the business process within the company to determine whether the solution is feasible to implement. The aspects examined are outlined in the Table 3 below.

Table 3 Feasibility Analysis and Company Perspective of Proposed Solution

No	Aspects	Analysis
1	Warehouse Capacity	By applying safety stock of 5.007 liter, reorder point of 16.366 liter and economic order quantity of 21.511 liter, the warehouse capacity is still sufficient to store the stock. Hence it is possible to apply the business solution within the company.
2	Procurement Contract	Company's policy and engine lubricant's procurement contract do not specifically limit the volume of each procurement or limit the reorder point. Also, there are no provisions limiting the number of orders that can be placed within a year. Hence, implementing repeat orders using economic order quantity of 21.511 per order is possible.
3	Business Process Workflow	Implementing the EOQ method within the company doesn't significantly change existing business processes, only changes in the number of orders placed and its quantity. Planner and procurement team can continue to operate their existing business process, but with EOQ method modified. So, there will be no potential problems in implementing the EOQ method within the company.
4	Company Perspective	The operational team acknowledged that the current inventory policy often leads to shortages and emergency procurement. Therefore, the EOQ approach is perceived as an improvement in planning and cost control. This business solution can be tested with regular monitoring to determine its effectiveness.

Various aspects within the company are assessed to know whether the proposed solutions are feasible to implement. Besides that, the company's point of view also be assessed. Overall, the proposed solutions are feasible to implement.

Implementation Plan and Justification

The implementation plan and justification are to ensure the successful implementation of the proposed inventory management improvements within the company. This plan will guide the company to adopt the EOQ model, maintaining safety stock, and establishing reorder points, to optimize the inventory management practices. The implementation plan will be phased over a six-month period to ensure a smooth adjustment. The implementation plan is showed in the Table 4 below.

Table 4 Implementation Plan

No	Activities	PIC	Month					
			1	2	3	4	5	6
	Preparation and Planning							
1	Project kickoff	Team Program						
2	Data collection	Team Program						
3	Training and development	Human Resources						
	Action							
4	EOQ calculation	Team Program						
5	Strategy testing	Team Program						
6	Full-scale implementation	Supervisor of Planning						
7	Inventory adjustment	Supervisor of Planning						
8	Performance monitoring	Supervisor of Planning						
	Evaluation							
9	Project review and evaluation	Team Program						
10	Continuous improvement	Team Program & Supervisor of Planning						

The justification of this implementation plan is the need for better service level and finding the potential cost efficiency of the inventory for the company. It can be achieved by calculating appropriate safety stock, reorder point, EOQ model. This approach aimed to optimize the inventory level and lower inventory cost of engine lubricant, especially within Jakarta operational area, and does not rule out the possibility to be implemented for each operational areas within the company.

CONCLUSION

1. The optimal inventory level of engine lubricant to provide adequate improvement of service level from around 78% to potentially 98% in Jakarta operational area is by providing 5.007 liter of safety stock (SS) per week and replenish the stock when reach the reorder point (ROP) of 16.366 liter.
2. By calculating EOQ, Jakarta operational area can cut its inventory cost amounted Rp 112.085.709. Economic order quantity (EOQ) model can potentially optimize inventory level, reduce inventory cost, and prevent shortage of engine lubricant in Jakarta operational area.
3. In the future research, try calculate and apply the safety stock, ROP, and EOQ method to other operational areas or other inventories to see if it also provides effectiveness. The optimization also can be tried to other divisions, other industries, company's subsidiaries, etc. EOQ model also can be compared with other possible inventory management models to see which is better.

LIMITATION

1. This research will focus specifically on Jakarta operational area within the sample of transportation service company, by examining engine lubricant's inventory.

2. The focus on the specific strategies may limit the exploration of alternative approaches to inventory management.
3. Since the study in centered on transportation service industry within the specific operational area, the findings may not be universally applicable to different sectors or industry. This limits the external validity of the research.
4. The findings may be context-specific to the operational environment of the company and its operational areas and might require adaptation for broader applicability.

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