



Analysis of Determining Order Quantity of Spare Parts in Oil and Gas Well Service Activities Using Monte Carlo Simulation

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Abstract

This research aims to explore the analysis of determining the order quantity of spare parts in well service activities in the oil and gas (Migas) industry using the Monte Carlo simulation approach. The Migas industry requires efficient inventory management to maintain operational smoothness, but this need must be balanced with efforts to minimize excessive storage costs. Therefore, it is important to determine the optimal order quantity to meet operational needs while avoiding unnecessary inventory accumulation. The Monte Carlo simulation method was chosen because of its ability to address uncertainty in inventory analysis, allowing for modeling variations in demand, delivery lead times, and other factors affecting inventory management. It is expected that this approach will provide a better understanding of how decisions regarding the order quantity can be made more effectively in the context of well service activities in the Migas industry. The main expectation of this research is the development of a model that can assist Migas companies in optimizing the management of their spare parts inventory. Thus, it is hoped that this research will make a significant contribution to improving operational efficiency, reducing storage costs, and increasing customer service levels in the Migas industry. It is also hoped that the results of this research will pave the way for the development of inventory management strategies that are more adaptive and responsive to dynamic business environments.

Introduction

The oil and gas (oil and gas) industry is an important and complex economic sector. In this industry, Well Service activities have a vital role in maintaining the production and performance of oil and gas wells. In Well Service, the use of appropriate and efficient spare parts is very important to maintain smooth operations and prevent disruptions that can stop production (Hasan et al., 2020; Ramos et al., 2020).

Well Service activities can be integrated into oil and gas well maintenance programs. In this activity process, spare parts are needed as a very crucial requirement to ensure operations in well service activities. The need for spare parts varies significantly depending on several factors, including well operational conditions and projected maintenance activities (Achouch et al., 2022; Sgarbossa et al., 2021; Abbas & Shafiee, 2020; Cheng et al., 2020). With the importance of spare parts in the well service process, the number of orders or order quantity often becomes a challenge or obstacle, especially for oil and gas companies, and it can be seen in figure 1 that there are several types of spare parts used in the HWU Rig operation process (Hmadeh, 2021).

Analysis of determining order quantities for spare parts requires a mature and careful approach. One technique that can be used is Monte Carlo simulation. Monte Carlo simulation is a numerical method used to model various possible scenarios by taking into account the uncertainty and variation of parameters that influence the process. In this context, Monte Carlo simulation can be applied to estimate spare parts requirements based on the probability distribution of various variables that influence well service activities (Farhadi et al., 2022; Srivastava et al., 2020; Afsahi & Shafiee, 2020; Feng et al., 2021; Barabadi et al., 2021).

By using Monte Carlo simulation, oil and gas companies can make it easier to identify order quantities that can be optimized for each type of spare part by operationally calculating various factors that can influence these needs. This simulation process allows oil and gas companies to reduce the risk of inventory shortages or excesses, as well as optimize capital expenditures related to purchasing spare parts (Zhu et al., 2020; Calvacante et al., 2020; Sylvester et al., 2022; Vazquez Hernandez & Elizondo Rojas, 2024). The resulting operational efficiency can be maximized in goods or contributions to other performance in oil and gas companies.

For example, oil and gas well service companies (Migas) have several types of equipment and spare parts needed to carry out well service activities. Accurate data relevant for this research may include (Priadi et al., 2014; Handoko et al., 2015): (1) Historical Demand: Data about historical demand for each type of spare part over a certain time period, for example the last year. This includes the quantity and frequency of demand for each item, as well as any seasonal patterns or long-term trends that may exist; (2) Lead Time: Information regarding lead time or the time required from ordering spare parts until delivery arrives at the location. This includes estimated delivery times from different suppliers; (3) Desired Service Level: Criteria or standards for the service level desired by the company, such as the fill rate or percentage of orders that can be fulfilled within the specified time; (4) Carrying Costs: Costs associated with storing inventory, including warehouse costs, insurance, and risk of obsolescence or damage; (5) Ordering Costs: Costs related to the spare parts ordering process, such as administration costs or shipping costs.

In terms of current conditions regarding inventory management, there is still quite a lack of demand for goods, which for each order is sometimes still less than the number of goods we expect, and sometimes there are more. And the system for ordering goods can be done several times a year. And for stock of inventory items, if the location that is most frequently used is close to our safety stock, a storeman is sometimes confused about estimating how many items we need (Halevi & Halevi, 2014), because the storeman at the location also plays an important role in determining the number of items he will submit it to the inventory management person for order (Vrat & Vrat, 2014) And spare parts that are out of stock at that location are an obstacle for us in carrying out operational activities and are not optimal.

So, the importance of inventory control refers to the process of managing and controlling the inventory of goods or materials in an organization or company (Mbugi & Lutego, 2022; Kairu, 2015; Bose, 2006; Ajayi et al., 2021). The importance of inventory control lies in its ability to optimize the use of company resources, reduce storage costs, and minimize the risk of unnecessary stock shortages or excess stock. By exercising effective control over inventory, companies can increase their operational efficiency, improve customer service, and increase profitability (Rubel, 2021; Yankah et al., 2022).

One of the main benefits of inventory control is its ability to maintain a balance between demand and supply. By having the right amount of inventory at the right time, companies can avoid lost sales due to stock shortages, while also avoiding the costs associated with storing excess goods (Taleizadeh et al., 2021; Sheffi, 2021). Apart from that, inventory control also helps companies plan production and distribution more efficiently, minimize the risk of

damage or expired goods, and increase visibility into the supply chain as a whole. Thus, inventory control plays a crucial role in maintaining the smooth operations and sustainability of the company's business (Panigrahi et al., 2021).

The Economic Order Quantity (EOQ) method is usually used in continuous review systems, where inventory is checked continuously and orders are placed according to needs when inventory reaches a certain level (Aguh et al., 2022; Milewski & Milewski, 2022). However, in cases where a company only orders once a year, EOQ may not be completely appropriate because EOQ is based on the assumption that orders can be placed regularly and in the right quantities when inventory reaches the reorder point.

For situations where the company only orders once a year, other approaches such as the fulfillment cycle method (periodic review) may be more appropriate. In this method, inventory is checked at certain time intervals (e.g. every month or every quarter) and orders are placed to meet requirements during the next period. Thus, companies can adapt their inventory management strategies to the ordering patterns they use (Blanchard, 2021).

Apart from the Economic Order Quantity (EOQ) method, there are several other methods that can be considered in the analysis of determining the order quantity for spare parts in oil and gas well service activities, including the Just-In-Time (JIT) method and the reorder point method (Ekpudu et al., 2022). The EOQ method is often considered better than other methods because it is simple in concept and easy to implement. EOQ produces optimal order quantities by minimizing total inventory costs, including ordering costs and holding costs. However, the EOQ method has several underlying assumptions, such as constant demand and definite lead times, which may not always apply in the context of complex oil and gas well service activities. Therefore, the use of Monte Carlo simulations in this research is expected to provide a more comprehensive insight into the various scenarios that may occur and help overcome the limitations of the EOQ method.

Table 1. History Non-Productive Time (NPT)

| Month | Type of Problems | NPT (Hours) | Description |
|-----------------------------------|-------------------|-------------|--|
| November | Waiting equipment | 17:00 | The company is still looking for a replacement for the load cell on the 16 th . |
| Total Time NPT = 17:00 Jam | | | |
| Month | Type of Problems | NPT (Hours) | Description |
| December | Waiting equipment | 10:30 | Repaired power barrel and waiting for spare parts on the 16 th . |
| Total Time NPT = 10:30 Jam | | | |

From the table above, the company has experienced Non-Productive Time (NPT), where the operational process cannot run for some time because one of the units cannot work optimally, so repairs or replacement of spare parts have to be carried out, while the spare parts stock is not available, so you have to wait for some time. Thus, Monte Carlo simulation can still be used to assist in determining the optimal number of orders and identifying the risks associated with orders in each month or period. By combining historical data and possible variations, these simulations can help companies make better decisions regarding their inventory management, even though they do not fit directly into the EOQ model.

So according to the dissemination of the data above, the aim is to increase operational efficiency and reliability in oil and gas well service activities by determining the optimal number of spare parts orders. By having the right amount of inventory, companies can avoid shortages or excesses of spare parts, which can disrupt operations and increase costs. It is

hoped that the analysis carried out through Monte Carlo simulations can provide more accurate and reliable recommendations in optimizing spare part order quantity determination. By looking at this background, this research aims to provide insight and practical recommendations for oil and gas well service companies in managing spare part order quantity effectively, optimizing operations, and reducing unnecessary costs.

Methods

This study utilizes a quantitative approach, specifically focusing on inventory management for spare parts in oil and gas well service activities through Monte Carlo simulation. The Monte Carlo method was selected due to its robustness in handling uncertainty and variability, which are inherent in inventory systems. The simulation allows for the modeling of complex scenarios by generating a probability distribution for critical variables such as demand, lead time, and service levels. Data was gathered on historical demand for three key spare parts: O-Rings, fuel filters, and ring gaskets, which are essential components in the maintenance and repair of oil and gas wells. These data sets were analyzed to determine demand patterns, delivery times, and the corresponding impact on inventory management. The simulation runs multiple iterations to predict spare part needs across various operational conditions, ensuring that the probability of stock shortages or excesses is minimized. The final model provides optimized recommendations for order quantities, aiming to reduce storage costs while maintaining service reliability. This method offers a comprehensive approach to spare parts management, enabling the company to improve operational efficiency and adapt to dynamic business environments.

Literature Review

From the explanation above, it can be seen that research related to inventory management in Well Service activities at PT. LKN by considering product substitution has not been carried out, so this provides an opportunity for the author to research or develop further regarding this matter. Table 2 below is the position of the research when compared to previous studies.

Table 2. Comparison of Previous Research Topics

| Research Title | EOQ | ROP | MCS |
|--|-----|-----|-----|
| Determination of Order Quantity and Reorder Point for Spare Parts at PT.X by Calculating Inventory Costs Through Non-Linear Programming Method | ✓ | ✓ | |
| Inventory Management by Considering Substitute Products in Dual Channel Supply Chain Structure | ✓ | | |
| EOQ and SS Analysis in Spare Parts Industry Especially Anodes with Monte Carlo Simulation | ✓ | ✓ | ✓ |
| A New Procedure for Spare Parts Inventory Management in ETO Production: A Case Study | ✓ | ✓ | |

Table 3. Comparison Table of Previous Research

| Report Name | Background | Analysis Results |
|---|--|---|
| Determination of Order Quantity and Reorder Point For Spare Parts at PT.X by Calculating Inventory Costs Through Non-Linear | A brief introduction about PT.X and the importance of inventory management in the company's operations. Details about spare parts and components that must be managed efficiently to maintain availability and avoid unnecessary costs. | Summary of the significance of the research results and potential applications in company operations. Mentioning the importance of using the Non-Linear Programming method to optimize the process of determining Order quantity and Reorder Point. |

| | | |
|---|---|--|
| Programming Method | | |
| Inventory Management Considering Substitute Products in Dual Channel Supply Chain Structure | An introduction to the dual channel supply chain structure involving two distribution channels, such as direct sales and sales through distributors. An introduction to the concept of substitute products, where similar products can be used to replace each other. | Identify the impact of substitute products on inventory decisions in each distribution channel. |
| | An introduction to the dual channel supply chain structure involving two distribution channels, such as direct sales and sales through distributors. An introduction to the concept of substitute products, where similar products can be used to replace each other. | Assess how interactions between distribution channels impact inventory levels. |
| EOQ and SS Analysis in Spare Part Industry, Especially Anodes with Monte Carlo Simulation | Introduction to the importance of inventory management, especially in the spare parts industry. A brief explanation of anode components and their roles in various industrial applications. | Determination of optimal EOQ for anode components based on mathematical models. Calculation of the level of Safety Stock required to overcome uncertainty in demand or lead time. Monte Carlo simulation results depicting the probabilistic distribution EOQ and SS decisions. |
| A New Procedure For Spare Parts Inventory Management In ETO Production: A Case Study | An introduction to the Engineer-to-Order (ETO) manufacturing environment, where each product is made to a specific order. An explanation of the complexities of inventory management in an ETO environment, particularly with regard to spare parts. | Development of new procedures that incorporate aspects such as demand planning, replacement parts, and application of Lean principles. Demonstration of the effectiveness of new procedures through case studies that illustrate improvements in production efficiency and inventory management. |

Results and Discussion

Monte Carlo Simulation on Order Quantity

Monte Carlo simulation can be used in the context of Well Service orders to address the uncertainties that may occur in the maintenance and care process of oil or gas wells. In this situation, Monte Carlo simulation can help understand the variations in maintenance time, costs, and risks associated with well servicing. Here is a further explanation.

Identify Uncertain Variables

Identify factors that have an element of uncertainty in the well servicing process. This can include the time required to complete the service, the costs involved, and the potential risks that may occur.

Table 4. Sparepart Name and Quantity Usage Period Month

| Order Date | Nama Sparepart | Quantity | Type | Unit |
|------------|--|----------|-----------|------|
| 09/01/22 | CARTRIDGE FILTER 5MICRON 10INX1/06"X2/5" | 200 | Sparepart | EA |
| 21/02/22 | FILTER, FUEL; WATER SEPARATOR; RACOR; 900FH | 5 | Sparepart | EA |
| 21/03/22 | NIPPLE, HEX; A105; 2IN; 3000PSI | 11 | Sparepart | EA |
| 24/04/22 | CHECK VALVE: 2- 1/2IN; PRESSURE PN16 | 1 | Sparepart | EA |
| 15/05/22 | LIP SEAL (PUMP); PARKER; 391-2883-103 | 2 | Sparepart | EA |
| 15/06/22 | LIP SEAL PUMP; PARKER; 391-2883-052 | 3 | Sparepart | EA |
| 12/07/22 | LIP SEAL, 391-2883-115 | 4 | Sparepart | EA |
| 15/08/22 | FILTER, FUEL; SPIN- ON; DONALDSON; P556915 | 12 | Sparepart | EA |
| 16/09/22 | FILTER, FUEL; SPIN- ON; SECONDARY; P556 916 | 14 | Sparepart | EA |
| 26/10/22 | GASKET; BX-155; 4- 1/16; WOLAR | 10 | Sparepart | EA |
| 26/11/22 | O-RING; 90D; 3- 3/8IN; KOP; 8.34040 | 13 | Sparepart | EA |
| 13/12/22 | HYD FILTER; DONALDSON; P171616 | 20 | Sparepart | EA |

Table 5. Spare Part Demand for Each Monthly Period

| No | Requests /Month | Amount |
|--------------------|-----------------|-----------|
| 1 | 1 | 1 |
| 2 | 2 | 1 |
| 3 | 3 | 1 |
| 4 | 4 | 1 |
| 5 | 5 | 1 |
| 6 | 10 | 1 |
| 7 | 11 | 1 |
| 8 | 12 | 1 |
| 9 | 14 | 1 |
| 10 | 13 | 1 |
| 11 | 20 | 1 |
| 12 | 200 | 1 |
| Grand Total | | 12 |

Determine the Probability Distribution

Based on historical data, technical knowledge, or expert estimates, select an appropriate probability distribution to represent the variation in the uncertain variable. This may involve a normal distribution, a log-normal distribution, or other distributions depending on the variable being analyzed. After obtaining the number of each request or F, then you can calculate the fixed Probability Value and the random limit on each spare part request. The calculation to determine the Probability value is as follows: $Probability = \frac{F Value}{Grand Total}$

Table 6. Probability Values for Spare Part Products

| Month | Number of Requests per Month | Probability |
|----------|------------------------------|-------------|
| January | 1 | 0,083333333 |
| February | 1 | 0,083333333 |
| March | 1 | 0,083333333 |
| April | 1 | 0,083333333 |

| | | |
|-----------|---|-------------|
| May | 1 | 0,083333333 |
| June | 1 | 0,083333333 |
| July | 1 | 0,083333333 |
| August | 1 | 0,083333333 |
| September | 1 | 0,083333333 |
| October | 1 | 0,083333333 |
| November | 1 | 0,083333333 |
| December | 1 | 0,083333333 |

After searching for the Probability data, then continue with the Cumulative calculation. For the calculation, use a formula like:

$$\text{Cumulative} = \text{Probabilitas Nilai A} + \text{Probabilitas Nilai B} \quad (3.2)$$

Table 7. Cumulative Value for Sparepart Products

| Month | Requests per Month | Probability | Cumulative |
|-----------|--------------------|-------------|-------------|
| January | 1 | 0,083333333 | 0,083333333 |
| February | 1 | 0,083333333 | 0,166666667 |
| March | 1 | 0,083333333 | 0,25 |
| April | 1 | 0,083333333 | 0,333333333 |
| May | 1 | 0,083333333 | 0,416666667 |
| June | 1 | 0,083333333 | 0,5 |
| July | 1 | 0,083333333 | 0,583333333 |
| August | 1 | 0,083333333 | 0,666666667 |
| September | 1 | 0,083333333 | 0,75 |
| October | 1 | 0,083333333 | 0,833333333 |
| November | 1 | 0,083333333 | 0,916666667 |
| December | 1 | 0,083333333 | 1 |

Searching for Random Values

Use a random algorithm to generate a series of random values from a chosen probability distribution. This will generate possible scenarios based on uncertainty. After obtaining the Probability and Cumulative values, continue by searching for random values, which can then be used to simulate the spare parts to be processed. Determination of this random value is based on the results of the Cumulative calculation as follows:

Table 8. Internal Random for Sparepart Products

| Month | Cumulative | Interval Random |
|-----------|-------------|-----------------|
| January | 0,083333333 | 00 – 08 |
| February | 0,166666667 | 08 – 16 |
| March | 0,25 | 16 – 25 |
| April | 0,333333333 | 25 – 33 |
| May | 0,416666667 | 33 – 41 |
| June | 0,5 | 41 - 50 |
| July | 0,583333333 | 50 - 58 |
| August | 0,666666667 | 58- 66 |
| September | 0,75 | 66- 75 |
| October | 0,833333333 | 75 – 83 |
| November | 0,916666667 | 83 – 91 |
| December | 1 | 91 – 100 |

Run Simulation

Use the generated random values to run the simulation repeatedly. In the context of a Well Service order, this would involve a simulation for each service period or well maintenance iteration. The random values in question are values from 0.00 - 0.100

Table 9. Random Number Values for Spareparts

| Month | Random | Random *100 |
|-----------|-------------|-------------|
| January | 0.052985141 | 5.298514125 |
| February | 0.695355588 | 69.53555876 |
| March | 0.375780803 | 37.57808027 |
| April | 0.37130413 | 37.13041303 |
| May | 0.171615546 | 17.16155464 |
| June | 0.889840567 | 88.98405673 |
| July | 0.448368601 | 44.83686013 |
| August | 0.384479568 | 38.44795682 |
| September | 0.811295327 | 81.12953272 |
| October | 0.769778004 | 76.97780038 |
| November | 0.377552576 | 37.75525762 |
| December | 0.545339933 | 54.53399328 |

Simulation Results

In each simulation iteration, calculate relevant results, such as total service cost, service time, or possible risk impacts. This will help in understanding the variation of results based on uncertainty.

Table 10. Calculating Results for Sparepart Products

| No | Month | Initial Quantity | Interval Random | Random* | Prediction Simulation |
|---|-----------|------------------|-----------------|-------------|-----------------------|
| 1 | Januari | 200 | 00 – 08 | 5.298514125 | 200 |
| 2 | Februari | 5 | 08 – 16 | 69.53555876 | 14 |
| 3 | Maret | 11 | 16 – 25 | 37.57808027 | 2 |
| 4 | April | 1 | 25 – 33 | 37.13041303 | 2 |
| 5 | Mei | 2 | 33 – 41 | 17.16155464 | 11 |
| 6 | Juni | 3 | 41 - 50 | 88.98405673 | 13 |
| 7 | Juli | 4 | 50 - 58 | 44.83686013 | 3 |
| 8 | Agustus | 12 | 58- 66 | 38.44795682 | 2 |
| 9 | September | 14 | 66- 75 | 81.12953272 | 10 |
| 10 | Oktober | 10 | 75 – 83 | 76.97780038 | 10 |
| 11 | November | 13 | 83 – 91 | 37.75525762 | 2 |
| 12 | Desember | 20 | 91 – 100 | 54.53399328 | 4 |
| Grand Total Simulation Prediction Next Year | | | | | 273 |

Result Analysis

After the simulation is complete, you will have a set of results from various iterations. Analysis of these results will provide insight into the probability distribution of possible outcomes. Based on the calculation results above, it is concluded that in the coming year the estimated spare parts that we will order are 273, and we will also compare this data with the data from the previous year to be one of our references as well as whether there will be an increase or decrease. And the possibility that the most spare parts ordered are of the type "CARTRIDGE FILTER 5 MICRON 10INX1 / 06" X2 / 5" is considered 200.

Decision Making

Based on the simulation results, we can make more informed decisions about service scheduling, cost allocation, risk mitigation, and long-term planning for well maintenance.

The application of Monte Carlo simulation to Well Service orders helps deal with the complexity and uncertainty in well service operations. This allows us to plan and manage services more efficiently and effectively, while considering the variations and risks that exist.

In the explanation above, some data will be exemplified to be calculated, according to the data that has been received when conducting field observations. The results of the decisions or decision-making in the calculations above are only used as a reference in conducting safety stock so as to find out the surge in demand for spare part orders in oil and gas well services and avoid shortages of goods or spare parts if urgently needed during installation. And the Monte Carlo calculation on this topic has answered the identification of problems that occurred previously, so that this calculation is quite effective in predicting demand in the period of Year, Month or day.

Analysis and Interpretation

After verification and the next stage, the results are analyzed regarding the results obtained from the data processing results. The analysis to be carried out includes data analysis of the use of the amount or quantity used during the implementation of Well Service and optimization and sensitivity testing using the Monte Carlo method or simulation. Running a Monte Carlo simulation will analyze the results. This may include identifying important statistics such as averages, standard deviations, quartiles, and others. And analyze how likely various results are, such as total inventory costs, based on the simulation results.

Analysis of Spare Part Demand Calculation in 2022

O-Ring Spare Part

Table 11. O-Ring Spare Part Data 2022 (Source: PT. LKN Company Data)

| No. | Entry Date | Description | Qty | Amt In Loc Curr | Unit |
|-----|------------|-------------|-----|-----------------|------|
| 1 | 10-1-2022 | O-RING SEAL | 15 | Rp 2,400,000.00 | EA |
| 2 | 17-1-2022 | O-RING SEAL | 20 | Rp 3,200,000.00 | EA |
| 3 | 2-2-2022 | O-RING SEAL | 8 | Rp 1,280,000.00 | EA |
| 3 | 13-2-2022 | O-RING SEAL | 12 | Rp 1,920,000.00 | EA |
| 4 | 8-3-2022 | O-RING SEAL | 12 | Rp 1,920,000.00 | EA |
| 5 | 10-3-2022 | O-RING SEAL | 25 | Rp 4,000,000.00 | EA |
| 6 | 30-3-2022 | O-RING SEAL | 6 | Rp 960,000.00 | EA |
| 7 | 11-4-2022 | O-RING SEAL | 4 | Rp 640,000.00 | EA |
| 8 | 19-4-2022 | O-RING SEAL | 8 | Rp 1,280,000.00 | EA |
| 9 | 22-4-2022 | O-RING SEAL | 20 | Rp 3,200,000.00 | EA |
| 10 | 20-5-2022 | O-RING SEAL | 6 | Rp 960,000.00 | EA |
| 11 | 28-5-2022 | O-RING SEAL | 9 | Rp 1,440,000.00 | EA |
| 12 | 7-6-2022 | O-RING SEAL | 3 | Rp 480,000.00 | EA |
| 13 | 20-6-2022 | O-RING SEAL | 20 | Rp 3,200,000.00 | EA |
| 14 | 8-7-2022 | O-RING SEAL | 4 | Rp 640,000.00 | EA |
| 15 | 14-7-2022 | O-RING SEAL | 20 | Rp 3,200,000.00 | EA |
| 16 | 19-7-2022 | O-RING SEAL | 12 | Rp 1,920,000.00 | EA |
| 18 | 12-8-2022 | O-RING SEAL | 5 | Rp 800,000.00 | EA |
| 19 | 20-8-2022 | O-RING SEAL | 15 | Rp 2,400,000.00 | EA |
| 20 | 5-9-2022 | O-RING SEAL | 5 | Rp 800,000.00 | EA |
| 21 | 6-9-2022 | O-RING SEAL | 8 | Rp 1,280,000.00 | EA |

| | | | | | | |
|--------------|------------|-------------|------------|-------------------------|--------------|----|
| 22 | 15-9-2022 | O-RING SEAL | 10 | Rp | 1,600,000.00 | EA |
| 23 | 23-9-2022 | O-RING SEAL | 8 | Rp | 1,280,000.00 | EA |
| 24 | 14-10-2022 | O-RING SEAL | 6 | Rp | 960,000.00 | EA |
| 25 | 31-10-2022 | O-RING SEAL | 5 | Rp | 800,000.00 | EA |
| 26 | 14-11-2022 | O-RING SEAL | 1 | Rp | 160,000.00 | EA |
| 27 | 29-11-2022 | O-RING SEAL | 15 | Rp | 2,400,000.00 | EA |
| 28 | 30-11-2022 | O-RING SEAL | 9 | Rp | 1,440,000.00 | EA |
| 29 | 24-12-2022 | O-RING SEAL | 12 | Rp | 1,920,000.00 | EA |
| 30 | 27-12-2022 | O-RING SEAL | 1 | Rp | 160,000.00 | EA |
| Total | | | 304 | Rp 48,640,000.00 | | |

Table 12. O-Ring Sparepart Data 2023 (Source: PT. LKN Company Data)

| No. | Entry Date | Description | Qty | Amt in Loc Curr | Unit | |
|--------------|------------|-------------|------------|-------------------------|------|--|
| 1 | 07/01/2023 | O-RING SEAL | 1 | Rp 160,000.00 | EA | |
| 2 | 17/01/2023 | O-RING SEAL | 20 | Rp 3,200,000.00 | EA | |
| 3 | 10/02/2023 | O-RING SEAL | 15 | Rp 2,400,000.00 | EA | |
| 4 | 15/02/2023 | O-RING SEAL | 4 | Rp 640,000.00 | EA | |
| 5 | 20/02/2023 | O-RING SEAL | 10 | Rp 1,600,000.00 | EA | |
| 6 | 27/02/2023 | O-RING SEAL | 2 | Rp 320,000.00 | EA | |
| 7 | 01/03/2023 | O-RING SEAL | 12 | Rp 1,920,000.00 | EA | |
| 8 | 14/03/2023 | O-RING SEAL | 9 | Rp 1,440,000.00 | EA | |
| 9 | 09/04/2023 | O-RING SEAL | 8 | Rp 1,280,000.00 | EA | |
| 10 | 20/04/2023 | O-RING SEAL | 2 | Rp 320,000.00 | EA | |
| 11 | 07/05/2023 | O-RING SEAL | 12 | Rp 1,920,000.00 | EA | |
| 12 | 24/05/2023 | O-RING SEAL | 6 | Rp 960,000.00 | EA | |
| 13 | 25/05/2023 | O-RING SEAL | 4 | Rp 640,000.00 | EA | |
| 14 | 12/06/2023 | O-RING SEAL | 1 | Rp 160,000.00 | EA | |
| 15 | 14/06/2023 | O-RING SEAL | 2 | Rp 320,000.00 | EA | |
| 16 | 21/06/2023 | O-RING SEAL | 6 | Rp 960,000.00 | EA | |
| 17 | 24/06/2023 | O-RING SEAL | 5 | Rp 800,000.00 | EA | |
| 18 | 03/07/2023 | O-RING SEAL | 2 | Rp 320,000.00 | EA | |
| 19 | 07/07/2023 | O-RING SEAL | 10 | Rp 1,600,000.00 | EA | |
| 20 | 11/07/2023 | O-RING SEAL | 15 | Rp 2,400,000.00 | EA | |
| 21 | 16/08/2023 | O-RING SEAL | 5 | Rp 800,000.00 | EA | |
| 22 | 19/08/2023 | O-RING SEAL | 10 | Rp 1,600,000.00 | EA | |
| 23 | 30/08/2023 | O-RING SEAL | 1 | Rp 160,000.00 | EA | |
| 24 | 12/09/2023 | O-RING SEAL | 7 | Rp 1,120,000.00 | EA | |
| 25 | 17/09/2023 | O-RING SEAL | 2 | Rp 320,000.00 | EA | |
| 26 | 25/09/2023 | O-RING SEAL | 2 | Rp 320,000.00 | EA | |
| 29 | 11/10/2023 | O-RING SEAL | 3 | Rp 480,000.00 | EA | |
| 30 | 18/10/2023 | O-RING SEAL | 6 | Rp 960,000.00 | EA | |
| 31 | 26/10/2023 | O-RING SEAL | 6 | Rp 960,000.00 | EA | |
| 32 | 06/11/2023 | O-RING SEAL | 3 | Rp 480,000.00 | EA | |
| 33 | 30/11/2023 | O-RING SEAL | 4 | Rp 640,000.00 | EA | |
| 34 | 02/12/2023 | O-RING SEAL | 6 | Rp 960,000.00 | EA | |
| 35 | 05/12/2023 | O-RING SEAL | 3 | Rp 480,000.00 | EA | |
| Total | | | 204 | Rp 32,640,000.00 | | |

The data above includes the history of demand for o-ring seals from 2022 and 2023, where from the 2 years the total demand was 304 EA in 2022 and 204 EA in 2023. This data will

be used as the basis for determining each demand based on the month by finding the value of the mean and sigma as in table 12.

Table 13. Calculation of Mean and Sigma Sparepart O-Ring Seal 2022 & 2023

| | Forecast Demand | | | | | | | | | | | |
|--------------|-----------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| | Jan-22 | Feb-22 | Mar-22 | Apr-22 | May-22 | Jun-22 | Jul-22 | Aug-22 | Sep-22 | Oct-22 | Nov-22 | Des-22 |
| Mean | 18 | 10 | 14 | 11 | 8 | 12 | 12 | 10 | 8 | 6 | 8 | 7 |
| Sigma | 4 | 2 | 10 | 8 | 2 | 12 | 8 | 7 | 2 | 1 | 7 | 8 |
| | Forecast Demand | | | | | | | | | | | |
| | Jan-23 | Feb-23 | Mar-23 | Apr-23 | May-23 | Jun-23 | Jul-23 | Aug-23 | Sep-23 | Oct-23 | Nov-23 | Des-23 |
| Mean | 11 | 8 | 11 | 5 | 7 | 4 | 9 | 5 | 4 | 5 | 4 | 5 |
| Sigma | 13 | 6 | 2 | 4 | 4 | 2 | 7 | 5 | 3 | 2 | 1 | 2 |

This data shows the mean and sigma values from 2022 & 2023, where we will use this data later as a basis for finding the trial value which will be carried out as many as 250 trials per each average value. The mean or average is a value that represents a set or group of data. The mean is obtained by adding up all individual data in a group, then dividing it by the number of individuals in the group. And the sigma value is a symbol used to write a short sum.

To find out the results of the trial or experiment values that have been carried out in this study, see Appendix 5 for the calculation of the O-Ring Seal for the 2 years. As explained above, this study carried out 250 trials in each average value. Where the average value will be used later in determining the most optimal value in ordering.

Table 14. Known Data (Source: PT. LKN Company Data)

| | | | |
|----------------------------|-----|---------------------------------|---------|
| Contract Demand | 175 | Demand Charge Rate per EA | 160,000 |
| Percentages | 85% | Penalty Charge Rate Percentages | 40% |
| Minimum Guaranteed Demand | 149 | Penalty Charge Rate per EA | 64,000 |
| Contract Demand (Decision) | 200 | Unutilized Demand Charge | 40,000 |

The data in table 4.4 is data that has been obtained from the field to determine a total prediction for o-ring seal demand in the previous 2 years. After that, the results of the average value were collected per each random trial (250 trials in 1 trial) and then we entered them into a table to determine the value of the most optimal results for ordering, as in table 4.5.

Table 15. Determination of the Optimal Point of O-Ring Seal Spareparts in 2024

| Contract Demand | Average Penalty Charge | Average Unutilized Charge | Relevant Cost |
|-----------------|------------------------|---------------------------|---------------|
| 175 | 81693 | 1078495 | 1160187 |
| 180 | 276881 | 946664 | 1223545 |
| 185 | 430376 | 677390 | 1107766 |
| 190 | 430376 | 677390 | 1107766 |
| 195 | 430376 | 677390 | 1107766 |
| 200 | 348495 | 600409 | 948903 |
| 205 | 721150 | 384250 | 1105400 |
| 210 | 856086 | 232738 | 1088824 |
| 215 | 852913 | 329026 | 1181939 |
| 220 | 1650797 | 141126 | 1791923 |
| 225 | 1273826 | 227220 | 1501045 |

Overall, this prediction data provides an overview of the possibilities that could arise. Data from the average penalty value and the average value of excess goods are obtained from the results of random trials. Then after that, to determine the value of the relevant cost, the average value of the penalty charge and the average value of the unutilized charge are added together so that the relevant cost value can be obtained. So that after we know the value of the relevant cost, we can determine the most optimal point, which is the smallest relevant cost value.

Sparepart Fuel Filter

Table 16. Data Sparepart Fuel Filter 2022 (Source: PT. LKN Company Data)

| No | Entry Date | Description | Qty | Amt In Loc Curr | Unit |
|--------------|------------|-----------------------|------------|-------------------------|------|
| 1 | 13-1-2022 | FILTER FUEL DONALDSON | 10 | Rp 1,600,000.00 | EA |
| 2 | 17-1-2022 | FILTER FUEL DONALDSON | 8 | Rp 1,280,000.00 | EA |
| 3 | 22-1-2022 | FILTER FUEL DONALDSON | 10 | Rp 1,600,000.00 | EA |
| 3 | 10-2-2022 | FILTER FUEL DONALDSON | 10 | Rp 1,600,000.00 | EA |
| 4 | 14-2-2022 | FILTER FUEL DONALDSON | 2 | Rp 320,000.00 | EA |
| 5 | 13-3-2022 | FILTER FUEL DONALDSON | 10 | Rp 1,600,000.00 | EA |
| 6 | 23-3-2022 | FILTER FUEL DONALDSON | 18 | Rp 2,880,000.00 | EA |
| 7 | 12-4-2022 | FILTER FUEL DONALDSON | 10 | Rp 1,600,000.00 | EA |
| 8 | 24-4-2022 | FILTER FUEL DONALDSON | 12 | Rp 1,920,000.00 | EA |
| 9 | 12-5-2022 | FILTER FUEL DONALDSON | 10 | Rp 1,600,000.00 | EA |
| 10 | 24-5-2022 | FILTER FUEL DONALDSON | 5 | Rp 800,000.00 | EA |
| 11 | 16-6-2022 | FILTER FUEL DONALDSON | 5 | Rp 800,000.00 | EA |
| 12 | 24-6-2022 | FILTER FUEL DONALDSON | 7 | Rp 1,120,000.00 | EA |
| 13 | 14-7-2022 | FILTER FUEL DONALDSON | 7 | Rp 1,120,000.00 | EA |
| 14 | 24-7-2022 | FILTER FUEL DONALDSON | 6 | Rp 960,000.00 | EA |
| 15 | 5-8-2022 | FILTER FUEL DONALDSON | 15 | Rp 2,400,000.00 | EA |
| 16 | 8-8-2022 | FILTER FUEL DONALDSON | 4 | Rp 640,000.00 | EA |
| 18 | 4-9-2022 | FILTER FUEL DONALDSON | 1 | Rp 160,000.00 | EA |
| 19 | 18-9-2022 | FILTER FUEL DONALDSON | 30 | Rp 4,800,000.00 | EA |
| 20 | 6-10-2022 | FILTER FUEL DONALDSON | 4 | Rp 640,000.00 | EA |
| 21 | 19-10-2022 | FILTER FUEL DONALDSON | 2 | Rp 320,000.00 | EA |
| 22 | 8-11-2022 | FILTER FUEL DONALDSON | 4 | Rp 640,000.00 | EA |
| 23 | 11-11-2022 | FILTER FUEL DONALDSON | 8 | Rp 1,280,000.00 | EA |
| 24 | 13-12-2022 | FILTER FUEL DONALDSON | 10 | Rp 1,600,000.00 | EA |
| 25 | 20-12-2022 | FILTER FUEL DONALDSON | 36 | Rp 5,760,000.00 | EA |
| Total | | | 244 | Rp 39,040,000.00 | |

Table 17. O-Ring Sparepart Data 2023 (Source: PT. LKN Company Data)

| No. | Entry Date | Description | Qty | Amt in Loc Curr | Unit |
|-----|------------|-------------|-----|-----------------|------|
| 1 | 05/01/2023 | FILTER FUEL | 1 | Rp 160,000.00 | EA |
| 2 | 10/01/2023 | FILTER FUEL | 10 | Rp 1,600,000.00 | EA |
| 3 | 09/02/2023 | FILTER FUEL | 3 | Rp 480,000.00 | EA |
| 4 | 11/02/2023 | FILTER FUEL | 4 | Rp 640,000.00 | EA |
| 5 | 14/02/2023 | FILTER FUEL | 4 | Rp 640,000.00 | EA |
| 6 | 17/02/2023 | FILTER FUEL | 6 | Rp 960,000.00 | EA |
| 7 | 23/02/2023 | FILTER FUEL | 12 | Rp 1,920,000.00 | EA |
| 8 | 24/02/2023 | FILTER FUEL | 5 | Rp 800,000.00 | EA |
| 9 | 28/02/2023 | FILTER FUEL | 6 | Rp 960,000.00 | EA |
| 10 | 01/03/2023 | FILTER FUEL | 5 | Rp 800,000.00 | EA |

| | | | | | | |
|--------------|------------|-------------------------|----|----|--------------|----|
| 11 | 07/03/2023 | FILTER FUEL | 5 | Rp | 800,000.00 | EA |
| 12 | 10/03/2023 | FILTER FUEL | 6 | Rp | 960,000.00 | EA |
| 13 | 16/03/2023 | FILTER FUEL | 6 | Rp | 960,000.00 | EA |
| 14 | 25/03/2023 | FILTER FUEL | 20 | Rp | 3,200,000.00 | EA |
| 15 | 17/04/2023 | FILTER FUEL | 2 | Rp | 320,000.00 | EA |
| 16 | 31/04/2023 | FILTER FUEL | 7 | Rp | 1,120,000.00 | EA |
| 17 | 16/05/2023 | FILTER FUEL | 6 | Rp | 960,000.00 | EA |
| 18 | 22/05/2023 | FILTER FUEL | 4 | Rp | 640,000.00 | EA |
| 19 | 06/06/2023 | FILTER FUEL | 6 | Rp | 960,000.00 | EA |
| 20 | 15/06/2023 | FILTER FUEL | 1 | Rp | 160,000.00 | EA |
| 21 | 21/06/2023 | FILTER FUEL | 6 | Rp | 960,000.00 | EA |
| 22 | 06/07/2023 | FILTER FUEL | 10 | Rp | 1,600,000.00 | EA |
| 23 | 11/07/2023 | FILTER FUEL | 3 | Rp | 480,000.00 | EA |
| 24 | 14/08/2023 | FILTER FUEL | 6 | Rp | 960,000.00 | EA |
| 25 | 15/08/2023 | FILTER FUEL | 5 | Rp | 800,000.00 | EA |
| 26 | 23/08/2023 | FILTER FUEL | 2 | Rp | 320,000.00 | EA |
| 29 | 29/08/2023 | FILTER FUEL | 6 | Rp | 960,000.00 | EA |
| 30 | 05/09/2023 | FILTER FUEL | 1 | Rp | 160,000.00 | EA |
| 31 | 13/09/2023 | FILTER FUEL | 3 | Rp | 480,000.00 | EA |
| 32 | 20/10/2023 | FILTER FUEL | 2 | Rp | 320,000.00 | EA |
| 33 | 26/10/2023 | FILTER FUEL | 4 | Rp | 640,000.00 | EA |
| 34 | 01/11/2023 | FILTER FUEL | 10 | Rp | 1,600,000.00 | EA |
| 35 | 16/11/2023 | FILTER FUEL | 1 | Rp | 160,000.00 | EA |
| 36 | 29/11/2023 | FILTER FUEL | 4 | Rp | 640,000.00 | EA |
| 37 | 05/12/2023 | FILTER FUEL | 4 | Rp | 640,000.00 | EA |
| 38 | 18/12/2023 | FILTER FUEL | 6 | Rp | 960,000.00 | EA |
| 39 | 31/12/2023 | FILTER FUEL | 6 | Rp | 960,000.00 | EA |
| Total | 198 | Rp 28,480,000.00 | | | | |

The data above includes the history of fuel filter demand from 2022 and 2023, where from the 2 years the total demand was 244 EA in 2022 and 198 EA in 2023. This data will be used as the basis for determining each demand based on the month by finding the mean and sigma values as in table 17.

Table 18. Calculation of Mean and Sigma Sparepart O-Ring Seal 2022 & 2023

| | Forecast Demand | | | | | | | | | | | |
|--------------|-----------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| | Jan-22 | Feb-22 | Mar-22 | Apr-22 | May-22 | Jun-22 | Jul-22 | Aug-22 | Sep-22 | Oct-22 | Nov-22 | Dec-22 |
| Mean | 9 | 6 | 14 | 11 | 8 | 6 | 7 | 10 | 16 | 3 | 6 | 23 |
| Sigma | 1 | 6 | 6 | 1 | 4 | 1 | 1 | 8 | 21 | 1 | 3 | 18 |
| | Forecast Demand | | | | | | | | | | | |
| | Jan-23 | Feb-23 | Mar-23 | Apr-23 | May-23 | Jun-23 | Jul-23 | Aug-23 | Sep-23 | Oct-23 | Nov-23 | Dec-23 |
| Mean | 6 | 6 | 8 | 5 | 5 | 4 | 7 | 4 | 2 | 3 | 5 | 5 |
| Sigma | 6 | 3 | 7 | 4 | 1 | 3 | 5 | 3 | 1 | 1 | 5 | 1 |

This data shows the mean and sigma values from 2022 & 2023, where we will use this data later as a basis for finding the trial value which will be carried out as many as 250 trials per each average value. The mean or average is a value that represents a set or group of data. The mean is obtained by adding up all individual data in a group, then dividing it by the number of individuals in the group. And the sigma value is a symbol used to write a short sum.

To find out the results of the trial or experiment values that have been carried out in this study, see Appendix 5 for the calculation of the fuel filter for the 2 years. As explained above, this study carried out 250 trials in each average value. Where the average value will be used later in determining the most optimal value in ordering.

Table 19. Known Data (Source: PT. LKN Company Data)

| | | | |
|----------------------------|-----|---------------------------------|---------|
| Contract Demand | 150 | Demand Charge Rate per EA | 190,000 |
| Percentages | 85% | Penalty Charge Rate Percentages | 40% |
| Minimum Guaranteed Demand | 128 | Penalty Charge Rate per EA | 76,000 |
| Contract Demand (Decision) | 170 | Unutilized Demand Charge | 50,000 |

The data in table is data that has been obtained from the field to determine a total prediction for fuel filter demand in the previous 2 years. After that, the results of the average value were collected per each random trial (250 trials in 1 trial) and then we entered them into a table to determine the value of the most optimal results for ordering, as in table 19.

Table 20. Determination of the Optimal Point of Fuel Filter Spare Parts in 2024

| Contract Demand | Average Penalty Charge | Average Unutilized Charge | Relevant Cost |
|-----------------|------------------------|---------------------------|---------------|
| 150 | 57259 | 1874379 | 1931638 |
| 155 | 130067 | 1790967 | 1921034 |
| 160 | 415081 | 1217033 | 1632114 |
| 165 | 235887 | 1080365 | 1316253 |
| 170 | 597458 | 704011 | 1301469 |
| 175 | 773523 | 670990 | 1444514 |
| 180 | 754127 | 825488 | 1579615 |
| 185 | 911616 | 603552 | 1515168 |
| 190 | 1415789 | 393964 | 1809753 |
| 195 | 1600103 | 293392 | 1893494 |
| 200 | 2261418 | 144301 | 2405719 |

Overall, this prediction data provides an overview of the possibilities that could arise. Data from the average penalty value and the average value of excess goods are obtained from the results of random trials. Then after that, to determine the value of the relevant cost, the average value of the penalty charge and the average value of the unutilized charge are added together so that the relevant cost value can be obtained. So that after we know the value of the relevant cost, we can determine the most optimal point, which is the smallest relevant cost value.

Safety Stock Calculation

Here is the safety stock calculation for the O-Ring Data spare part type (2023):

Optimal Value = 200

Lead Time = 7 Days

Demand during Lead Time: 2

Using the EOQ formula, we can calculate the optimal number of items to order:

$$\text{Safety Stock} = \frac{\text{Lead Time} \times \text{Demand During Lead Time}}{\text{Optimal}}$$

$$\text{Safety Stock} = \frac{7 \times 2}{200}$$

$$\text{Safety Stock} = \frac{14}{200}$$

Safety Stock = 7 % (Predictions for 2024)

So the safety stock for the O-Ring Seal type spare part is 7% of the total Optimal Value of 200 units. This means that when the inventory reaches 14 units, a reordering process must be carried out as a way to prevent empty spare part stock. The following is the calculation of safety stock for the Data Filter Fuel type spare part (2023)

EOQ value = 170

Lead Time = 7 Days

Demand during Lead Time: 2

Using the Optimal formula, we can calculate the optimal number of items to order:

$$\text{Safety Stock} = \frac{\text{Lead Time} \times \text{Demand During Lead Time}}{\text{Optimal}}$$

$$\text{Safety Stock} = \frac{7 \times 2}{170}$$

$$\text{Safety Stock} = \frac{14}{170}$$

Safety Stock = 8 % (Predictions for 2024)

So, the safety stock for the Fuel Filter type spare part is 8% of the total optimal number of 170 units. This means that when the inventory reaches 14 units, a reordering process must be carried out as a way to prevent empty spare part stock.

Conclusion

The data is the result of the calculation of Economic Order Quantity (EOQ) for three different types of spare parts, namely Data O-Ring spare parts, Data Filter Fuel, and Data Ring Gasket, based on data from 2022 & 2023. (1) For Data O-Ring spare parts, the Optimal Value obtained for predictions in 2022 & 2023 is 200 units, while the results of the safety stock value obtained are at 7% which indicates the lowest point for reordering at 14 EA; (2) For Data Filter Fuel spare parts, the Optimal Value obtained for predictions in 2022 & 2023 is 170 units, while the results of the safety stock value obtained are at 8% which indicates the lowest point for reordering at 14 EA; (3) It is proven from this study that using the Monte Carlo method can reduce costs as indicated by the relevant cost results for the O-ring seal spare parts obtained, namely IDR 948,903. 1,301,469 while for fuel filter spare parts is Rp. 1,301,469. By conducting proper safety stock analysis, companies can better manage risks and ensure adequate availability for their customers.

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