

CHAPTER 4 – RESULTS AND DISCUSSIONS

4.1 Problem Discussion

In the fourth chapter, the condition of stock or spare parts inventory and PT's service level will be described. UT in serving its customers, namely PT. AMNT. Currently, there is a major problem where inventory values are high, while service levels are low. The high inventory value is expressed through the days of inventory (DOI) figure which exceeds the target. The level of service is shown through instant full availability, which has not yet reached the predetermined target. Current service measurements cover all requests from PT customers. AMNT, where the number of items cannot be determined because it depends on the condition of damage to the heavy equipment owned by PT. AMNT.

In this chapter, we will also explain the analysis carried out to determine the right spare parts so that the DOI can be reduced, while the service level can be increased, which is reflected through the full instant availability of PT spare parts requests. AMNT. In addition to determining spare parts, stock level determination will also be carried out, producing a list of stock item data along with minimum and maximum stock levels.

To determine spare parts and stock levels, calculations will be carried out quantitatively using a monthly spare parts movement approach for one year or what is known as month movement, as well as forecasting using historical demand data including the Simple Moving Average method. A qualitative approach will also be applied by considering information from customers, such as spare parts usage planning, unit damage trends, and predictions of future spare parts usage, including deterministic calculations based on the useful life of spare parts. With this method, criteria will be obtained that must be approved by PT. UT and PT. AMNT to determine what items will be used as stock by PT. AMNT and which will be purchased by PT. AMNT.

4.2 Data Collection

As context for key issues and analysis in finding solutions, we collect a variety of data, including service levels, days of inventory, inventory stock counts, and historical demand data. We got this data from the system at PT. UT site Sumbawa. It

is hoped that this data can become the basis for process improvements and be used as a reference for calculating appropriate inventory and stock levels.

a. Service level data

Service level data is the basis for identifying main problems, because from this information it can be seen how accurate the selection of items and determining stock levels are in meeting existing demand.

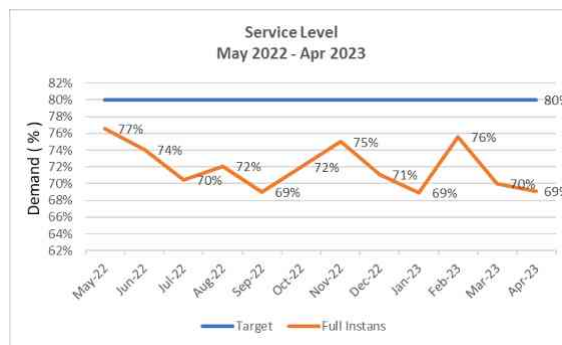


Figure 4.1 Service Level Graph in 2022

From Figure 4.1 it shows that the target of achieving a service level of 80% has never been achieved throughout 2022. The service level calculation is carried out by comparing the number of call frequencies that can be fulfilled with the stock in the PT warehouse. UT Sumbawa with the total frequency of all customer requests during 2022. The service level calculation can be simplified using the formula below:

$$\text{Service Level} = \frac{\text{Available demand frequencies}}{\text{all demand frequencies}} \times 100\% \quad (4.1)$$

b. Days of inventory and stock amount data

Days of Inventory (DOI) and Stock Amount are closely related. The amount of DOI is influenced by the amount of stock and sales volume of the part or product. This relationship can be detailed through the formula below:

$$\text{DOI} = \frac{\text{Stock Amount}}{\text{Average COGS in a certain period}} \times 30 \text{ Hari} \quad (4.2)$$

And here is the DOI and stock amount data for PT. UT Sumbawa during 2022, which is shown in Figure 4.2.



Figure 4.2 Days of Inventory

From this information, it can be concluded that the performance of Days of Inventory (DOI) at PT. UT Sumbawa is always below the set target. It is important to analyze the causes of these non-achievements to identify necessary corrective solutions.

c. Historical demand data

The collection of historical demand data is crucial information that will undergo processing in selecting stock items and determining stock levels. This historical demand data comes from PT transactions. UT Sumbawa to customers for one year in 2022. From this data, information will be obtained regarding demand and call frequency.

d. Interviews data

Information gathering through interviews with Parts Supply Chain Officers at UT Sumbawa and Supply Chain Supervisors from PT. AMNT revealed that the forecasting method applied in 2022 is as follows:

Based on the results of interviews with Parts Supply Chain Officer PT. UT, findings include:

- The forecasting method applied in 2022 is using the 12-month moving average method for all items that have undergone transactions, including those in the Fast moving and slow-moving categories.
- The stock ordering process is carried out every month.
- In determining the number of stock orders (qty order), it is calculated using the formula 1.5 times the estimate (forecast) every month.
- The service level is not achieved, and the reason is because there are many new items that have not been included in the forecasting calculations.

The following are the results of an interview with Supply Chain Supervisor PT. AMNT summarized:

- The service level from PT. UT Sumbawa has not achieved the target set at 80%.
 - Service level performance is 80%, which is desired by PT. AMNT, focuses on the Fast-moving category (Parts Periodical Service, Consumable Parts), and on spare parts that have transactions for 3 months a year.
- PT. AMNT is seeking resolutions to enhance the efficiency of fast-moving spare parts delivery, given its direct influence on machine productivity.

4.3 Data Processing

To facilitate the problem analysis process, the historical spare parts transaction data obtained from UT Sumbawa was grouped using the FSN Analysis method to obtain three classifications of goods, namely fast moving, slow moving and nonmoving (Devarajan Divya, Jayamohan MS, 2015). Each group of goods can be analyzed and managed differently.

Researchers classify by grouping the level of frequency of annual movements in each month which we call "Month Movement" which means how many months movements or transactions occur in each year. Table 4.1 will explain the distribution of spare parts based on Month Movement combined with FSN analysis.

Table 4.1 Classification of FSN Analysis

Month Movement	Classification
5 - 12 Month Movement	Fast Moving
1-4 Month Movement	Slow Moving
0 Month Movement	Non-Moving

From table 4.1, it is explained that the fastmoving spare parts category is transactions that occur within 5 months to 12 months of the year. Slow moving spare parts are spare parts that have transactions in 1 month to 4 months during a year, while non-moving spare parts are spare parts that have not been transacted within a year and are generally called "Dead Stock". So Non-moving stock is the same as Dead stock.

a. Stock Inventory data classification at the end of April 2023

From the stock data April 2023, a classification process using FSN Analysis can be applied. The results of the FSN analysis can also be seen how many items &

quantities spare parts, and what percentage of stock and DOI are in each group. With this data, the author can determine problem analysis and solutions for each group, and management for each group must be carried out differently. Classification data for the end of April is shown in table 4.2.

Table 4.2 Stock classification at the end of April 2023

Target DOI 90 Day

FSN Analysis	Item	Qty (Pcs)	Price x Rp 1 Million	Stock Percentage	DOI (Days)
Fast Moving	201	5638	2.204	18%	90
Slow Moving	567	5529	5.956	49%	100
Non Moving	730	2612	3.953	33%	∞
Grand Total	1498	13779	12.113	100%	285

If we break down the Days of Inventory (DOI) for each item, we can see that in each stock classification there are items that have a DOI that exceeds the target, as depicted in Table 4.3.

Table 4.3 Number of items that exceed the DOI target.

FSN Analysis	Item (Pcs)	Item Parts with DOI > 90 (Pcs)	Percentage
Fast Moving	201	101	50%
Slow Moving	567	501	88%
Non Moving	730	730	100%
Grand Total	1498	1332	89%

b. Service level data classification processing

Through processing demand data, a classification of service levels is obtained for each month. Details can be found in Table 4.4.

Table 4.4 Classification of monthly service levels

Target 80 %

Classification	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23
Fast Moving	88%	93%	88%	80%	76%	80%	82%	80%	87%	87%	85%	86%
Slow Moving	47%	26%	34%	29%	52%	35%	41%	40%	35%	36%	47%	31%
All Item	77%	74%	70%	72%	69%	72%	75%	71%	69%	76%	70%	69%

To evaluate service level data for the one-year, you can refer to Table 4.5.

Table 4.5 Classification of service level parts in 1 year

Target 80 %

Classification	Service Level target in 2022 - 2023 in 80%		
	Demand Available (Pcs)	Demand Not Available (Pcs)	%
Fast Moving	8733	1678	84%
Slow Moving	1517	2400	39%
All Item	10250	4078	72%

From the data analysis above, the service level for fast moving spare parts is met, while for slow moving spare parts it is not achieved. However, when broken down by item, there are items that are not available in both the fast moving and slow-moving groups.

4.4 Problem Analysis

After analyzing the data, several problems can be identified at PT. UT Sumbawa is related to service levels (Service Level, SL) and Days of Inventory (DOI). The main problem that was revealed was that service levels never reached the target during 2022 and Days of Inventory (DOI) also never reached the target set throughout 2022, as shown in Table 4.6.

Table 4.6 Main problems

DOI Target 90 Days & Service Level Target 80%			
Classification	DOI (Days)	Service Level	Note
Fast Moving	80	> 80 %	Achieve
Slow Moving	100 Days	< 80 %	DOI & Service Level not Achieve
Non Moving	∞	< 80%	DOI & Service Level not Achieve

4.5.1 Finding for the Root of the Problem using the 5 Why Diagram

Use the 5 Why method to identify the root of the problem, where the fifth reason is the root cause (Benjamin, Samuel Jebaraj, et all. 2015). The root cause search process is shown in Table 4.8.

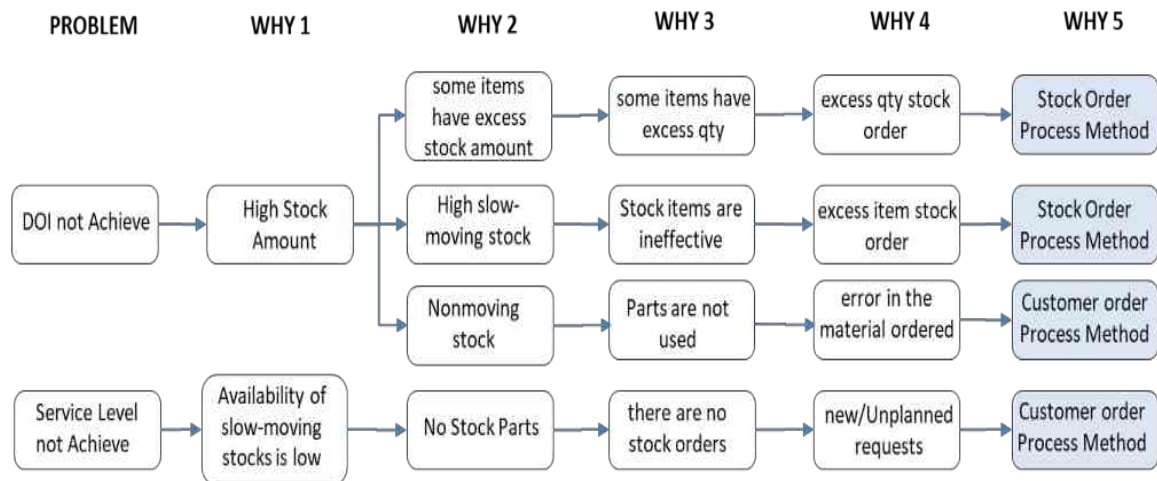


Figure 4.3 Diagram 5 Why

Through the 5 Whys analysis of Days of Inventory (DOI), the root problems identified involve two main aspects:

1. Order Processing Method for stock items.
2. Order Process Method for customer requests.

The causes of these two root problems can be identified as follows:

1. Order Process Method for stock.
 - Incorrect (inefficient) number of orders (Qty Order).
 - Incorrect (ineffective) selection of order items.
2. Order Process Method for customer requests.
 - Errors in providing spare parts recommendations.
 - There is a new request without a usage plan, so it is not available when the request arises.

4.5.2 Determining Solutions and Improvement Ideas

To formulate ideas for improvements or solutions to be taken, the step is to create a root cause and problem-solving table.

Table 4.7 Root Cause & Problem Solving.

Root Cause	Problem Identification	Corrective Action/ Improvement Idea	Methods
Method of orderProcess for stock	Incorrect handling of order items and quantities (Excess & Less)	Enhancing forecasting accuracy and order quantities	EOQ & Forecasting
Customer Order Process Method	Lack of diligence in customer order processing.	Preventing Order Process Error and Enhancing the Flow of the Order Process	Isikawa Diagram & Swiss Cheese model
	New requests reduce service levels because they are not accounted for in inventory forecasts.	Restriction in the coverage of measuring performance in service level using the VHS system	VHS & Task Analysis

From the data in Table 4.7, identified improvement activities include:

1. Improvements to forecasting methods.
2. Inventory control using the Economic Order Quantity (EOQ) method.
3. Order processing errors by employees and Improved Order Process Flow through the Swiss Cheese Model
4. Implementation of VHS to improve and measure service levels.

4.5 Improvement

4.5.1 Forecasting

Based on the analysis obtained from data collection and processing, it was found that demand data has an unstable pattern and does not have a regular trend or seasonality and there is no weighting, so a good forecasting method is to use quantitative methods and simple moving averages (M.M Ali, Babai M.Z et al, 2015).

In this research, the forecasting process will look for a Moving Average forecasting model by comparing 3 periods of time series data, namely 3-months, 6-months, and 12-months in 2022. Predictive analysis will include sampling products from both fast-moving and slow-moving categories. To assess the error level of each forecasting calculation, can using the Mean Absolute Deviation (MAD) method. (Yager, Ronald R. Alajlan, Naif. 2014).

4.5.1.1 Fast Moving Product Forecasting Testing in the past year

In fast moving parts, there is a problem of over DOI due to excess stock qty, however the service level is still achieved according to the target of 80%. In the fast-moving parts research, we will take 2 product samples which are considered to represent all product items. Product samples were selected for products with high DOI values and high amounts.

Table 4.8 Data *sampling* product *Fast Moving*

PARTS NUMBER	DESCRIPTION	DOI (Days)	AMOUNT (Rp)	In Qty (Pcs)											
				May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23
600-185-6110	FILTER	188	31.309.791	11	5	1	11	14	12	7	6	12	10	9	5
XS30TV	TOOTH	110	207.262.065	15	15	101	15	30	45	47	54	20	59	15	25

From table 4.8, the demand pattern for these two products tends to be stable over time. The demand data obtained is also quite large so it can be used for forecasting calculations within a certain period. So, from the time series pattern data

of the two fast moving products, according to Barry Render, Jay Heizer, Chuck Munson, 2020 the most appropriate forecasting method is the moving average method. To get the most accurate calculations, 3 types of time series data will be used, namely 3-months, 6-months, and 12-months, so that you can see the difference in accuracy that occurs in forecasting calculations with three types of time series data.

The equation employed for the Moving Average is:

$$F_t = (D_{t-1} + D_{t-2} + D_{t-3} + \dots + D_{t-n}) / n \quad (4.3)$$

F_t = Forecast in period t

D_t = Demand in the period t

The three forecasting processes will be tested for error with Mean Absolute Deviation (MAD). The results of the smallest error value are used to determine the best forecasting model that will be used for forecasting in the coming months.

a. Forecasting part number 600-185-6110 (Fast Moving Parts)

The Moving Average model forecasting calculation for January 2023 with a 12-month period is carried out as follows:

$$\begin{aligned} \text{Forecast Jan 2023} &= (\text{Actual Jan 2022} + \text{Actual Feb 2022} + \text{s/d Des 2022}) / 12 \quad (4.4) \\ &= (6+7+9+11+12+5+1+11+14+12+7+6) / 12 \\ &= 8,5 \end{aligned}$$

So, the forecasting result for January 2023 is = 8,5 Pcs.

Then the forecasting process is carried out for the next month until April 2023. The forecasting results are shown in table 4.9.

Tabel 4.9 Parts number forecasting results 600-185-6110

Parts Number	Month	Actual sales (Pcs)	Forecast Result (Pcs)			
			Naïve	12 Month Moving Average	6 Month Moving Average	3 Month Moving Average
600-185-6110	Jan-23	12	6	8,5	8,5	8,3
	Feb-23	10	12	9,0	10,3	8,3
	Mar-23	9	10	9,3	10,2	9,3
	Apr-23	5	9	9,3	9,3	10,3

There are differences in the forecasting results from the three calculated time periods. To find out which forecast is the most accurate, it is necessary to test the error of the results.

The MAD method calculation with a 4-month forecasting period is as follows:

$$MAD = \frac{\sum |E_t|}{n} \quad (4.5)$$

$$MAD = (\text{Total Absolute Value (Actual Demand – Forecasting Results)})/12 \quad (4.6)$$

The calculation results using the MAD method is shown in table 4.10.

Table 4.10 Results of forecasting testing 600-185-6110 with MAD

Parts Number	Month	Actual sales (Pcs)	Forecast Result (Pcs)				Absolut Deviation (Pcs)			
			Naïve	12 Month Moving Average	6 Month Moving Average	3 Month Moving Average	Naïve	12 Month	6 Month	3 Month
600-185-6110	Jan-23	12	6	8,5	8,5	8,3	6,0	3,5	3,5	3,7
	Feb-23	10	12	9,0	10,3	8,3	2,0	1,0	0,3	1,7
	Mar-23	9	10	9,3	10,2	9,3	1,0	0,3	1,2	0,3
	Apr-23	5	9	9,3	9,3	10,3	4,0	4,3	4,3	5,3
		138	Sum of Error				13,0	9,0	9,3	11,0
			MAD				3,3	2,3	2,3	2,8

The error level in forecasting product 600-185-6110 which was calculated using MAD was found to have the smallest value 2,25 in Moving Average forecasting with a time of 12 months. So, the moving average method with a 12-month time period can be chosen as the most appropriate forecasting model.

b. Forecasting part number XS30TV (Fast Moving Parts)

The Moving Average model forecasting calculation for January 2023 with a 12-month period is carried out as follows:

$$\begin{aligned} \text{Forecast Jan 2023} &= (\text{Actual Jan 2022} + \text{Actual Feb 2022} + \text{s/d Des 2022}) / 12 \quad (4.7) \\ &= (0+0+30+20+15+15+101+15+30+45+47+54) / 12 \\ &= 31,0 \end{aligned}$$

So, the forecasting result for January 2023 is = 31,0 Pcs

Then the forecasting process is carried out using Microsoft Excel to simplify and speed up the forecasting results for the following month up to April 2023. The forecasting results are shown in table 4.11.

Tabel 4.11 Parts number forecasting results XS30TV

Parts Number	Month	Actual sales (Pcs)	Forecast Result (Pcs)			
			Naïve	12 Month Moving Average	6 Month Moving Average	3 Month Moving Average
XS30TV	Jan-23	20	54	31,0	48,7	48,7
	Feb-23	59	20	32,7	35,2	40,3
	Mar-23	15	59	37,6	42,5	44,3
	Apr-23	25	15	36,3	40,0	31,3

There are differences in the forecasting results from the three calculated time periods. To find out which forecast is the most accurate, it is necessary to test the error of the results.

The MAD method calculation with a 4-month forecasting period is as follows:

$$MAD = \frac{\sum |Et|}{n} \quad (4.8)$$

MAD = (Total Absolute Value (Actual Demand – Forecasting Results)/ 12

The calculation results using the MAD method are shown in table 4.12.

Table 4.12 Results of forecasting testing XS30TV with MAD

Parts Number	Month	Actual sales (Pcs)	Forecast Result (Pcs)				Absolut Deviation (Pcs)			
			Naïve	12 Month Moving Average	6 Month Moving Average	3 Month Moving Average	Naïve	12 Month	6 Month	3 Month
XS30TV	Jan-23	20	54	31,0	48,7	48,7	34,0	11,0	28,7	28,7
	Feb-23	59	20	32,7	35,2	40,3	39,0	26,3	23,8	18,7
	Mar-23	15	59	37,6	42,5	44,3	44,0	22,6	27,5	29,3
	Apr-23	25	15	36,3	40,0	31,3	10,0	11,3	15,0	6,3
		491	Sum of Error				127,0	71,3	95,0	83,0
			MAD				31,8	17,8	23,8	20,8

The error level in forecasting product XS30TV which was calculated using MAD was found to have the smallest value 17,8 in Moving Average forecasting with a time of 12-months. So, the moving average method with a 12-month time can be chosen as the most appropriate forecasting model.

4.5.1.2 Testing Slow Moving Product Forecasts for the past year

In Parts Slow moving there is a problem of not achieving service level and DOI. We will take 2 product samples which are considered to represent all product items. Product samples are selected for products with a DOI value of more than 100 days and a high amount. The sample data is shown in table 4.13.

Table 4.13 Slow Moving product sampling data

PARTS NUMBER	DESCRIPTION	DOI	AMOUNT (Rp)	In Qty (Pcs)											
				May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23
207-30-00693	IDLER ASS'Y MO	414	230.827.017								2	2		2	4
56B-33-00110	FLOATING SEAL A	144	51.028.461	2	1	4		3							

For forecasting data, 3 types of time series data will be used, namely 3 months, 6 months, and 12 months, so that you can see the difference in accuracy that occurs in forecasting calculations with the three types of time series data.

The Moving Average Model employs the following formula:

$$F_t = \frac{(D_{t-1} + D_{t-2} + D_{t-3} + \dots + D_{t-n})}{n} \quad (4.9)$$

F_t=Forecast in period t

D_t=Demand in period t

The three forecasting processes will be tested for error with Mean Absolute Deviation (MAD). The results of the smallest error value are used to determine the best forecasting model that will be used for forecasting in the following month.

a. Forecasting part number 207-30-00693 (Slow Moving Parts)

The Moving Average model forecasting calculation for January 2023 with a 12-month period is carried out as follows:

$$\begin{aligned} \text{Forecast Jan 2023} &= (\text{Actual Jan 2022} + \text{Actual Feb 2022} + \text{s/d Des 2022}) / 12 \quad (4.10) \\ &= (0+0+0+0+0+0+0+0+0+0+0+2) / 12 \\ &= 0,2 \end{aligned}$$

So, the forecasting result for January 2023 is = 0,2 Pcs

Then the forecasting process is carried out using Microsoft Excel to simplify and speed up the forecasting results for the following month up to April 2023. The forecasting results are shown in table 4.14.

Tabel 4.14 Parts number forecasting results 207-30-00693

Parts Number	Month	Actual sales (Pcs)	Forecast Result (Pcs)			
			Naïve	12 Month Moving Average	6 Month Moving Average	3 Month Moving Average
207-30-00693	Jan-23	2	2	0,2	0,3	0,7
	Feb-23	0	2	0,3	0,7	1,3
	Mar-23	2	0	0,3	0,7	1,3
	Apr-23	4	2	0,5	1,0	1,3

There are differences in the forecasting results from the three calculated time periods. To find out which forecast is the most accurate, it is necessary to test the error of the results.

The MAD method calculation with a 4-month forecasting period is as follows:

$$MAD = \frac{\sum |Et|}{n} \quad (4.10)$$

$$MAD = (\text{Total Absolute Value (Actual Demand} - \text{Forecasting Results)} / 12$$

The calculation results using the MAD method are shown in table table 4.15.

Table 4.15 Results of forecasting testing 207-30-00693 with MAD

Parts Number	Month	Actual sales (Pcs)	Forecast Result (Pcs)				Absolut Deviation (Pcs)			
			Naïve	12 Month Moving Average	6 Month Moving Average	3 Month Moving Average	Naïve	12 Month	6 Month	3 Month
207-30-00693	Jan-23	2	2	0,2	0,3	0,7	0,0	1,8	1,7	1,3
	Feb-23	0	2	0,3	0,7	1,3	2,0	0,3	0,7	1,3
	Mar-23	2	0	0,3	0,7	1,3	2,0	1,7	1,3	0,7
	Apr-23	4	2	0,5	1,0	1,3	2,0	3,5	3,0	2,7
		8	Sum of Error				6,0	7,3	6,7	6,0
			MAD				1,5	1,8	1,7	1,5

The error level in forecasting product 207-30-00693 which was calculated using MAD was found to have the smallest value 1,5 in Moving Average forecasting with a time of 3 months. So, the moving average method with a time of 3 months can be chosen as the most appropriate forecasting model.

b. Forecasting part number 56B-33-00110 (Slow Moving Parts)

The Moving Average model forecasting calculation for January 2023 with a 12-month period is carried out as follows:

$$\begin{aligned}
 \text{Forecast Jan 2023} &= (\text{Actual Jan 2022} + \text{Actual Feb 2022} + \text{s/d Des 2022}) / 12 \quad (4.11) \\
 &= (0+0+1+0+2+1+4+0+3+0+0+0) / 12 \\
 &= 0
 \end{aligned}$$

So, the forecasting result for January 2023 is = 0,9 Pcs

Then the forecasting process is carried out using Microsoft Excel to simplify and speed up the forecasting results for the following month up to April 2023. The forecasting results are shown in table 4.16.

Tabel 4.16 Parts number forecasting results 56B-33-00110

Parts Number	Month	Actual sales (Pcs)	Forecast Result (Pcs)			
			Naïve	12 Month Moving Average	6 Month Moving Average	3 Month Moving Average
56B-33-00110	Jan-23	0	0	0,9	1,2	0,0
	Feb-23	0	0	0,9	0,5	0,0
	Mar-23	0	0	0,9	0,5	0,0
	Apr-23	0	0	0,8	0,0	0,0

There are differences in the forecasting results from the three calculated time periods. To find out which forecast is the most accurate, it is necessary to test the error of the results.

The MAD method calculation with a 4-month forecasting period is as follows:

$$MAD = \frac{\sum |Et|}{n} \quad (4.12)$$

MAD = (Total Absolute Value (Actual Demand – Forecasting Results)/ 12

The calculation results using the MAD method are shown in table 4.17.

Table 4.17 Results of forecasting testing 56B-33-00110 with MAD

Parts Number	Month	Actual sales (Pcs)	Forecast Result (Pcs)				Absolut Deviation (Pcs)			
			Naive	12 Month Moving Average	6 Month Moving Average	3 Month Moving Average	Naive	12 Month	6 Month	3 Month
56B-33-00110	Jan-23	0	0	0,9	1,2	0,0	0,0	0,9	1,2	0,0
	Feb-23	0	0	0,9	0,5	0,0	0,0	0,9	0,5	0,0
	Mar-23	0	0	0,9	0,5	0,0	0,0	0,9	0,5	0,0
	Apr-23	0	0	0,8	0,0	0,0	0,0	0,8	0,0	0,0
			Sum of Error				0,0	3,6	2,17	0,0
			MAD				0,0	0,9	0,5	0,0

The error level in forecasting product 56B-33-00110 which was calculated using MAD was found to have the smallest value 0 in Moving Average forecasting with a time of 3 months. So, the moving average method with a time of 3 months can be chosen as the most appropriate forecasting model.

Moving average forecasting with two classifications of fast moving and slow-moving parts by sampling 2 products each obtained different error results which are shown in Figure 4.4.

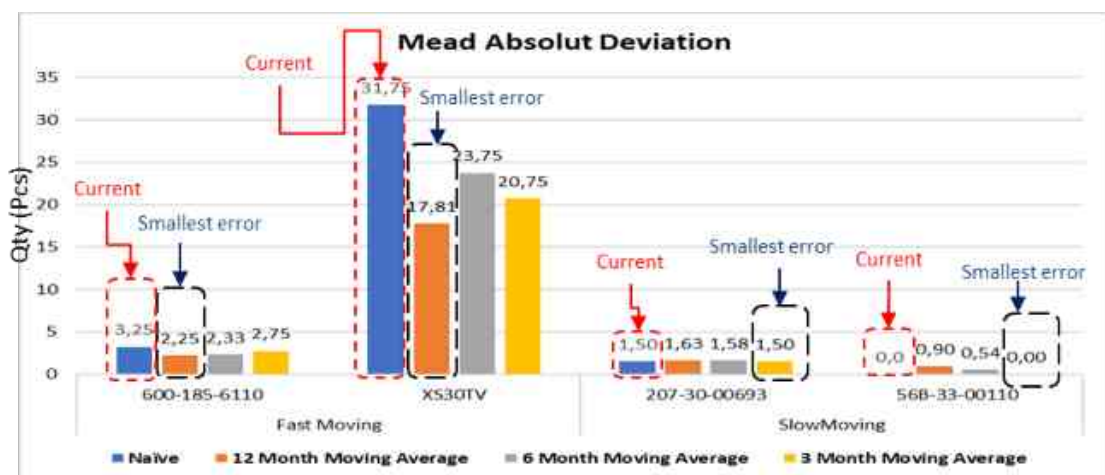


Figure 4.4 Error measurement results with MAD calculations

Based on the results of the MAD calculation which can also be seen in graph 4.3, the researcher proposed to the company PT. UT Sumbawa as follows:

- a. In fast-moving products, the best forecasting uses a moving average every 12 months.
- b. In slow-moving products, the best forecasting uses a moving average every 3 months.

4.5.2 Economic Order Quantity is utilized in managing inventory control.

Conducting inventory control is essential to reduce inventory costs, minimize the occurrence of stockouts affecting service levels, and enhance efficiency. The approach employed in this study is the Economic Order Quantity (EOQ) method (Rinaldi, Marta 2022).

In calculating inventory management costs, a unit price is required, which is obtained from the purchase price of spare parts from vendors for each unit, and for the annual storage cost per unit (H), the company standard (UT) is used, namely 8% of the purchase price. Every purchase from a UT vendor will incur a purchase fee of Rp. 100,000.00 (S).

a. Calculation of costs for PN 600-185-6110

- Calculation of actual costs without EOQ in the previous year

Table 4.18 Request, stock, and actual stock order PN 600-185-6110

Parts Number	Description	Not Using EOQ (Pcs)												
		Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23
600-185-6110	Demand	13	11	5	1	11	14	12	7	6	12	10	9	5
	Stock	10	10	25	40	37	24	29	43	55	53	52	61	71
	Supply	11	11	20	17	8	2	17	21	18	11	9	18	15
	Order Qty forecast	11	20	17	8	2	17	21	18	11	9	18	15	14
			13	11	5	1	11	14	12	7	6	12	10	9

1 year demand (D) = 103 Pcs

Unit Price = Rp. 1,944,068 (UT purchase price to Vendor)

Number of orders in 1 year = 12 times

Average inventory = 41Pcs

Storage costs per unit (H) = Rp. 155,525 (8% from Purchase Price – UT Standar)

Cost for each Order (S) = Rp. 100,000 (Cost of each purchase to Komatsu)

Annual procurement costs = Number of orders placed per year x S = 12 x 100,000
= Rp. 1,200,000

$$\begin{aligned}\text{Annual holding costs} &= \text{Average inventory} \times H \\ &= 41 \times \text{Rp. } 155,525 = \text{Rp. } 6,447,825 \\ \text{Total Actual Costs without EOQ} &= \text{Rp. } 1,200,000 + \text{Rp. } 6,447,825 \\ &= \text{Rp. } 7,647,825\end{aligned}$$

- Cost calculation if using EOQ in the previous year.

$$\text{Economic Order Qty (Q*)} = \frac{\sqrt{2DS}}{H} = \frac{\sqrt{2 \times 103 \times 100,000}}{155.525} = 11.5$$

$$\text{Number of orders in 1 year} = \frac{103}{11.5} = 9 \text{ times}$$

$$\begin{aligned}\text{Re-order Point d} &= D / \text{Quantity of months in a single year} \\ &= 103/12 = 8.58 = 9\end{aligned}$$

$$\begin{aligned}\text{Safety Stock} &= d \times \text{Safety factor for service level 80\% is } 0.84 \\ &= 9 \times 0.84 = 7 \text{ Pcs}\end{aligned}$$

$$\text{Average inventory} = 13 \text{ Pcs}$$

$$\begin{aligned}\text{ROP} &= (d \times \text{arrival time (L)}) + \text{Safety Stock} \\ &= (9 \times 1) + 7 \\ &= 16 \text{ Pcs}\end{aligned}$$

Table 4.19 Request, stock, and stock order PN 600-185-6110 if using EOQ.

Parts Number	Description	Using EOQ (Pcs)												
		Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23
600-185-6110	Demand	13	11	5	1	11	14	12	7	6	12	10	9	5
	Stock	10	10	17	16	17	3	3	8	14	14	16	19	14
	Supply	11	11	12	0	12	0	12	12	12	12	12	12	0
	Order Qty	11	12		12		12	12	12	12	12	12		12
	forecast		9	9	9	9	9	9	9	9	9	9	9	9
	ROP	16												

$$\begin{aligned}\text{Annual procurement costs} &= 9 \times \text{Rp. } 100,000 \\ &= \text{Rp. } 900,000\end{aligned}$$

$$\begin{aligned}\text{Annual holding costs} &= 13 \times \text{Rp. } 155,525 \\ &= \text{Rp. } 1,957,028\end{aligned}$$

$$\text{Total Cost with EOQ} = \text{Rp. } 900,000 + \text{Rp. } 1,957,028 = \text{Rp. } 4,790,797$$

$$\begin{aligned}\text{Efficiency using EOQ} &= \text{Total cost without EOQ} - \text{Total costs with EOQ} \\ &= \text{Rp. } 7,647,825 - \text{Rp. } 4,790,797 \\ &= \text{Rp. } 2,857,028\end{aligned}$$

b. Calculation of costs for PN XS30TV

- Calculation of actual costs without EOQ in the previous year

Table 4.20 Request, stock, and actual stock order PN XS30TV

Parts Number	Description	Not Using EOQ (Pcs)													
		Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23	
XS30TV	Demand	20	15	15	101	15	30	45	47	54	20	59	15	25	
	Stock	50	65	80	2	9	131	108	106	120	170	192	207	31	
	Supply	30	30	30	23	23	152	23	45	68	71	81	30	89	
	Order Qty	30	30	23	23	152	23	45	68	71	81	30	89	23	
	forecast		20	15	15	101	15	30	45	47	54	20	59	15	

1 year demand (D) = 441 Pcs

Unit Price = Rp. 1,409,946 (UT purchase price to Vendor)

Number of orders in 1 year = 12 times

Average inventory = 102 Pcs

Storage costs per unit (H) = Rp. 112,796 (8% from Purchase Price – UT Standar)

Cost for each Order (S) = Rp. 100,000 (Cost of each purchase to Komatsu)

Annual procurement costs = Number of orders placed per year x S = 12 x 100,000
= Rp. 1,200,000

Annual holding costs = Average inventory x H
= 102 x Rp.112,796 = Rp. 11,462,861

Total Actual Costs without EOQ = Rp.1,200,000+Rp. 11,462,861
= Rp. 12,662,861

- Cost calculation if using EOQ in the previous year.

Economic Order Qty (Q*) = $\sqrt{\frac{2DS}{H}} = \sqrt{\frac{2 \times 441 \times 100,000}{112,796}} = 28$

Number of orders in 1 year = $\frac{441}{28} = 16$ times

Re-order Point d = D/Quantity of months in a single year
= 441/12 = 37

Safety Stock = d x Safety factor for service level 80% is 0.84
= 37 x 0.84 = 31 Pcs

Average inventory = 45 Pcs

ROP = (d x arrival time (L)) + Safety Stock
= (37 x 1) + 31
= 68 Pcs

Table 4.21 Request, stock, and stock order PN XS30TV if using EOQ.

Parts Number	Description	Using EOQ (Pcs)													
		Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23	
XS30TV	Demand	20	15	15	101	15	30	45	47	54	20	59	15	25	
	Stock	50	65	50	5	46	44	27	36	38	74	43	56	59	
	Supply	30	30	0	56	56	28	28	56	56	56	28	28	28	
	Order Qty	30		56	56	28	28	56	56	56	28	28	28	28	
	forecast		34	34	34	34	34	34	34	34	34	34	34	34	
	ROP	68													

Annual procurement costs = 16 x Rp. 100,000

= Rp. 1,600,000

Annual holding costs = 45 x 112,796

= Rp. 5,104,005

Total Cost with EOQ = Rp. 1,600,000 + Rp. 5,104,005 = Rp. 6,704,005

Efficiency using EOQ = Total cost without EOQ – Total costs with EOQ

= Rp 12,662,861 – Rp. 6,704,005

= Rp. 5,958,856

c. Calculation of costs for PN 207-30-00693

- Calculation of actual costs without EOQ in the previous year

Table 4.22 Request, stock, and actual stock order PN 207-30-00693

Parts Number	Description	Not Using EOQ (Pcs)												
		Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23
207-30-00693	Demand	0	0	0	0	0	0	0	0	2	2	0	2	4
	Stock	2	2	2	2	2	2	2	2	0	1	4	5	4
	Supply	0	0	0	0	0	0	0	0	0	3	3	3	3
	Order Qty	0	0	0	0	0	0	0	0	3	3	3	3	3
	forecast		0	0	0	0	0	0	0	2	2	2	0	2

1 year demand (D) = 10 Pcs

Unit Price = Rp. 19,235,585 (UT purchase price to Vendor)

Number of orders in 1 year = 4 times

Average inventory = 2 Pcs

Storage costs per unit (H) = Rp. 1,536,847 (8% from Purchase Price, Standart UT)

Cost for each Order (S) = Rp. 100,000 (Cost of each purchase to Komatsu)

Annual procurement costs = Number of orders placed per year x S = 4 x 100,000 =
Rp. 400,000

Annual holding costs = Average inventory x H

= 2,33 x 1,536,847 = Rp.3,590,643

Total Actual Costs without EOQ = Rp.400,000 + Rp. 3,590,643

$$= \text{Rp. } 3,990,643$$

- Cost calculation if using EOQ in the previous year.

$$\text{Economic Order Qty (Q*)} = \frac{\sqrt{2DS}}{H} = \frac{\sqrt{2 \times 10 \times 100,000}}{1,538,847} = 1,14$$

$$\text{Number of orders in 1 year} = \frac{10}{1,14} = 9 \text{ times}$$

$$\begin{aligned} \text{Re-order Point d} &= D/\text{Quantity of months in a single year} \\ &= 10/12 = 0,83 \end{aligned}$$

$$\begin{aligned} \text{Safety Stock} &= d \times \text{Safety factor for service level 80\% is } 0.84 \\ &= 0,83 \times 0.84 = 0,7 \text{ Pcs} \end{aligned}$$

$$\text{Average inventory} = 2,17$$

$$\begin{aligned} \text{ROP} &= (d \times \text{arrival time (L)}) + \text{Safety Stock} \\ &= (0,8 \times 1) + 0,7 \\ &= 1,5 \text{ Pcs} \end{aligned}$$

Table 4.23 Request, stock, and stock order PN 207-30-00693 if using EOQ.

Parts Number	Description	Using EOQ (Pcs)												
		Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23
207-30-00693	Demand	0	0	0	0	0	0	0	0	2	2	0	2	4
	Stock	2	2	3	3	3	3	3	3	1	1	3	1	0
	Supply	0	0	1	0	0	0	0	0	0	2	2	0	3
	Order Qty	0	1							2	2		3	1
	forecast		1	1	1	1	1	1	1	1	1	1	1	1
	ROP	1,5												

$$\begin{aligned} \text{Annual procurement costs} &= 4 \times \text{Rp. } 100,000 \\ &= \text{Rp. } 400,000 \end{aligned}$$

$$\begin{aligned} \text{Annual holding costs} &= 2,17 \times 1,536,847 \\ &= \text{Rp. } 3,334,168 \end{aligned}$$

$$\text{Total Cost with EOQ} = \text{Rp. } 400,000 + \text{Rp. } 3,334,168 = \text{Rp. } 3,734,168$$

$$\begin{aligned} \text{Efficiency using EOQ} &= \text{Total cost without EOQ} - \text{Total costs with EOQ} \\ &= \text{Rp. } 3,990,643 - \text{Rp. } 3,734,168 \\ &= \text{Rp. } 256,474 \end{aligned}$$

d. Calculation of costs for PN 56B-33-00110

- Calculation of actual costs without EOQ in the previous year

Table 4.24 Request, stock, and actual stock order PN 56B-33-00110

Parts Number	Description	Not Using EOQ (Pcs)												
		Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23
56B-33-00110	Demand	0	2	1	4		3							
	Stock	2	2	1	0	2	5	5	9	9	9	9	9	9
	Supply	2	2	0	3	2	6	0	5	0	0	0	0	0
	Order Qty	2	0	3	2	6	0	5	0	0	0	0	0	0
	forecast		0	2	1	4	0	3	0	0	0	0	0	0

1 year demand (D) = 10 Pcs

Unit Price = Rp. 12,757,115 (UT purchase price to Vendor)

Number of orders in 1 year = 4 times

Average inventory = 7 Pcs

Storage costs per unit (H) = Rp. 1,020,569 (8% from Purchase Price – UT Standar)

Cost for each Order (S) = Rp. 100,000 (cost of each purchase to Komatsu)

Annual procurement costs = Number of orders placed per year x S = 4 x 100,000 =
Rp. 400,000

Annual holding costs = Average inventory x H
= 7 x 1,020,569 = 7,143,984

Total Actual Costs without EOQ = Rp. 400,000 + Rp. 7,143,984
= Rp. 7,543,984

- Cost calculation if using EOQ in the previous year.

Economic Order Qty (Q*) = $\frac{\sqrt{2DS}}{H} = \frac{\sqrt{2 \times 10 \times 100,000}}{1,020,569} = 1,4$

Number of orders in 1 year = $\frac{10}{1,4} = 7$ times

Re-order Point d = D/Quantity of months in a single year
= 10/12 = 0,83

Safety Stock = d x Safety factor for service level 80% is 0.84
= 0,83 x 0.84 = 0,7 Pcs

Average inventory = 1 Pcs

ROP = (d x arrival time (L)) + Safety Stock
= (0,8 x 1) + 0,7
= 1,5 Pcs

Table 4.25 Request, stock, and stock order PN 56B-33-00110 if using EOQ.

Parts Number	Description	Using EOQ (Pcs)												
		Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	Apr-23
56B-33-00110	Demand	0	2	1	4		3							
	Stock	2	2	1	0	1	0	1	1	1	1	1	1	1
	Supply	2	2	0	3	1	2	1	0	0	0	0	0	0
	Order Qty	2		3	1	2	1							
	forecast	0	1	1	1	1	1	1	1	1	1	1	1	1
	ROP	1,5												

Annual procurement costs = 7 x 100,000

= Rp. 700,000

Annual holding costs = 1 x 1,020,569

= Rp. 1,020,569

Total Cost with EOQ = Rp. 400,000 + Rp. 1,020,569 = Rp. 1,720,569

Efficiency using EOQ = Total cost without EOQ – Total costs with EOQ

= Rp 7,543,984 – Rp. 1,720,569

= Rp. 5,823,415

Of the four products that have been simulated by comparing the existing order process without EOQ and the EOQ method, results are obtained as in table 4.26.

Table 4.26 Comparison between Existing and EOQ.

Description	Parts Number							
	600-185-6110		XS30TV		207-30-00693		56B-33-00110	
	Without EOQ	EOQ	Without EOQ	EOQ	Without EOQ	EOQ	Without EOQ	EOQ
Q*		11,5		28		1,14		1,4
Procurement Cost (Rp)	1.200.000	900.000	1.200.000	1.600.000	400.000	400.000	400.000	700.000
Storage Cost (Rp)	6.447.826	3.875.105	11.462.861	5.104.005	3.590.643	3.334.168	7.143.984	1.020.569
Total Cost (Rp)	7.647.826	4.775.105	12.662.861	6.704.005	3.990.643	3.734.168	7.543.984	1.720.569
Efisiensi with EOQ	2.872.721		5.958.856		256.474		5.823.415	

By referring to table 4.26, it is evident that the Economic Order Quantity (EOQ) results in lower costs compared to the actual order process from the preceding year. Therefore, the researcher recommends the implementation of the EOQ method at PT. UT Sumbawa in 2023.

4.5.3 Prevent order processing errors by employees through analysis with the Swiss Cheese Model

The failure to achieve Days of Inventory (DOI) at PT. UT Sumbawa can be attributed, in part, to the presence of non-moving stock in the heavy equipment parts

inventory. This occurs when a customer cancels an order after acquiring parts from the vendor or principal, resulting in the received parts becoming non-moving stock in the warehouse. Consequently, this situation contributes to an elevation in inventory levels and an increase in DOI at PT. UT Sumbawa.

After conducting an interview with the Parts Supply Chain Officer at PT. UT Sumbawa as inventory manager, researchers obtained data and information that the customer order cancellation incident was due to an error or mismatch between the parts number ordered and the customer's heavy equipment requirements. These errors have the potential to occur repeatedly, the most common causes being errors in recommending parts numbers to customers and errors in entering parts order numbers into the system.

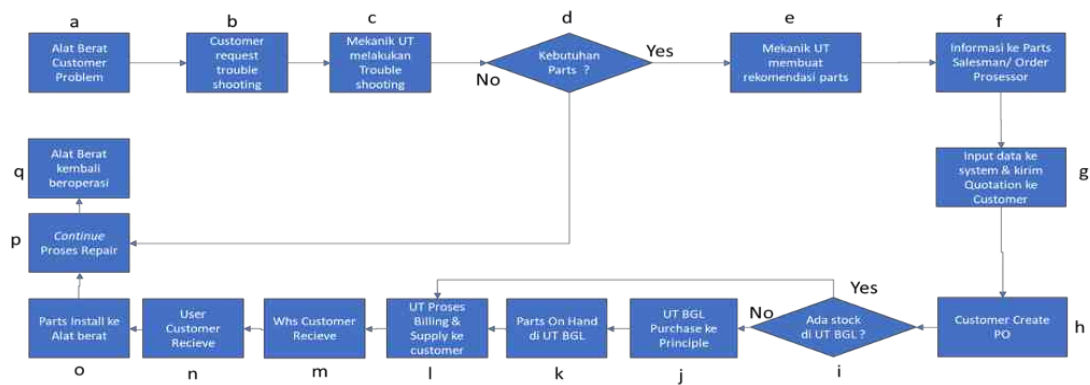


Figure 4.5 Flow Chart Customer Order Parts

Referring from, Figure 4.5, it becomes apparent that the process error initiates at step (e), involving the mechanic's error in recommending parts numbers. Subsequently, at step (g), errors arise in the input of parts numbers by both the customer order processor (COP) and the parts salesman.

a. Parts Number Recommendation Error.

Parts recommendation errors are caused by the process of making recommendations and lack of supervision over the results of the recommendations, with detailed causes as follows:

1. Mechanics who lack knowledge in reading parts books, unit models and unit serial numbers.
2. Parts books that are damaged and worn make it difficult for mechanics to read parts numbers.

3. Digital parts books or soft files are only available on computers in the office and are not available in the field or mechanical work locations.
4. There is no supervision and no checking of recommendation data before the data is sent to the COP or parts salesman.

b. Parts Number Input Error.

Errors in inputting parts number data into the system and quotations are caused by carelessness in parts salesmen and customer order processors which are influenced by several things, namely:

1. Not focused because there are too many customers being served.
2. Lack of responsibility because they don't know the impact of mistakes.
3. Inputting data by typing has the potential for typographical errors, because the data obtained by parts salesmen and customer order processors is in the form of hard copy or handwritten.
4. There is no supervision and data checking before quotation to the customer.

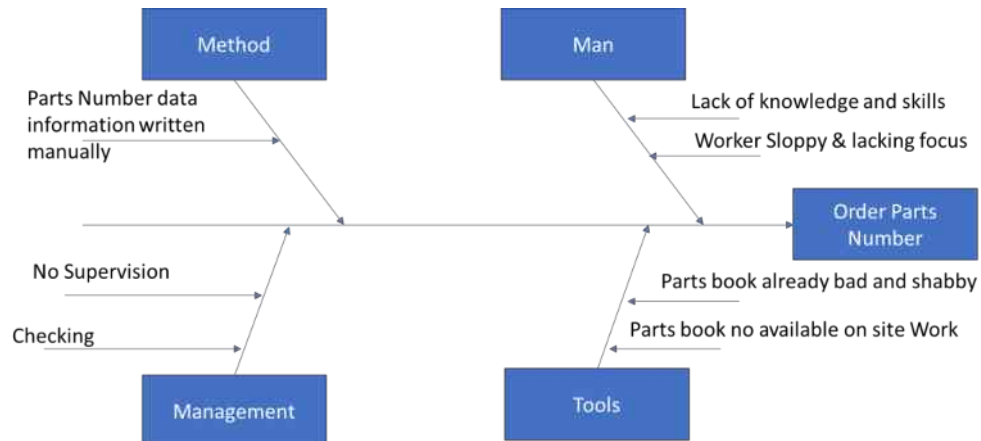


Figure 4.6 Ishikawa diagram of parts number order errors

After creating an Ishikawa diagram shown in Figure 4.6, several root causes of errors can be identified, including Man, Method, Management and Tools, which will then be carried out further analysis to get the right solution so that repeated errors do not occur.

c. Human Factors Analysis

This research uses a Swiss cheese model analysis where there are four levels including unsafe actions, prerequisites for unsafe actions, unsafe supervision, and organizational influences which will then be developed to further analyse the risk of conditions that cause errors in order parts numbers and result in non-moving stock.

Table 4.27 Swiss Cheese Model for Parts Number Order Errors.

Unsafe Actions		
Error	Skills Based	Unable to identify the required part number according to the component required, tool model specifications and serial number.
	Decision	Lack of sense of responsibility.
	Perceptual	Not understanding the impact that will occur if an error occurs in inputting the parts number.
Routine Violations	There is no checking of the parts number as a result of the recommendation from the mechanic.	
	There is no checking of the parts number quotation made by parts <i>salesman or customer order processor</i> .	
Prerequisites for unsafe actions		
Environmental factor	Physique	Parts books that are damaged, worn and poorly maintained can cause errors in reading the parts number
	Technology	Digital parts books or soft files are only used on computers in the office and are not available in the field or mechanical work locations.
		Transfer parts number information manually
Operator Conditions	Mental State	Lack of focus and lack of motivation
	Physiological	Not found
	Physical/Mental Limitations	Not found
Personal Factors	Crew Resource Management	Not found
	Personal Readiness	Lack of knowledge
		Less responsible
Unsecure Surveillance		
Inadequate Supervision	Supervisors don't provide enough coaching and mechanics don't have enough knowledge about reading parts books	
Plan for Inappropriate Surgery	Not found	
Failed to Fix Known Issues	Not found	
Violation Monitoring	There is no standard form for checking the results of recommendations by the supervisor	
Organizational Influence		
Resource Management	Lack of training events and refreshment of parts book reading	
Organizational Climate	Lack of supervision	
	There are no rewards and punishments	
Operational Process	There is no re-examination of the results of recommendations and quotations	

From Table 4.27 was found that the mechanic was unable to identify the parts number due to lack of knowledge of reading the parts book. And the damaged condition of the parts book causes an increase in the possibility of errors occurring. The inability to use digital parts books because they are far from the mechanic's work area also makes these tools less able to prevent errors.

Supervisors are important in this condition to supervise, monitor, check and control every task carried out by the mechanics, especially when making part number recommendations. Supervisors must be able to ensure mechanics use the correct parts book and provide coaching on how to read the parts book correctly. With proper supervision, errors will be prevented in recommending parts that will be given to customers.

In the work of inputting data and making quotations by the COP and Parts Salesman this is also the cause of parts number order errors. Factors of carelessness, lack of focus and lack of responsibility of workers are the biggest causes in this case. Workers do not understand the consequences that will arise if an error in the parts number occurs during the data input process, so they do not exercise caution and double-check when inputting data. Inputting data by manually typing the part numbers one by one also has the potential for typographical errors, because the data received is in manual form or hard copy. Apart from that, fatigue is also the cause of COPs and Salesmen not focusing on inputting quotation data.

Supervision or data validation checks on Quotations are very necessary before the quotation is sent to the customer. One step of Supervision is required after making a quotation to prevent parts number order errors.

Mechanical workers and customer order processors have low levels of education and skills, so management must pay more attention to these conditions. Regular training and refresher training should be carried out to ensure workers' skills and knowledge. An understanding of the impact of mistakes made on the company must also be given to workers on a regular basis. An organizational climate must be provided to ensure good working conditions for workers. Rewards and punishments can also be applied to encourage workers' motivation to work properly and more thoroughly. Standards and guidelines for carrying out tasks are one thing that must be provided to ensure that standards for work quality, product quality and service quality for customers are met properly.

The suggestions provided to employees, supervisors, and companies for averting errors in parts number orders, as identified through the Swiss Cheese Model analysis, include:

1. Management provides regular coaching to employees, especially mechanics, COPs, and Parts Salesmen to ensure employees have sufficient knowledge and sense of responsibility in their work.
2. Daily briefing at the morning meeting to make recommendations for parts numbers and make quotations correctly, and provide an understanding of the impact of incorrect parts number orders for the company,
3. Establish a systematic and consistent training program to refresh employees' knowledge of reading parts books.
4. Offering mechanics closer access to digital parts book facilities, so they can be accessed in the field, whether they can be accessed via gadgets, laptops, and computers.
5. Supervisors need to maintain discipline in overseeing the preparation of parts number recommendations.
6. Introduce an extra validation step conducted by supervisors following the parts number recommendation process and quotation generation.
7. Establish a work system incorporating incentives and consequences to enhance employee motivation for improved and meticulous performance while nurturing a sense of responsibility.

4.5.4 Vendor Held Stock (VHS) System for Improving and Measuring Service Level

In accordance with the results of data collection and processing, the service level was not achieved due to slow moving stock with a service level achievement of only 39%.

a. Service Level Calculation Coverage

According to the 5 Why analysis in figure 4.3 and data on the contribution of not available slow-moving parts in table 4.28, the biggest cause of parts not being available is the demand for new parts. A request is classified as "new" if it has occurred only a maximum of twice in the last 12 months. Such items cannot be predicted using historical data.

Table 4.28 Contribution of Slow-Moving Items to not available parts

Movement (Month)	Not Available Item (Pcs)	Not Available Contribution (%)	Description
1	1134	47%	New Demand
2	614	26%	New Demand
3	274	11%	
4	368	15%	
Total Item Slow Moving	2390	100%	

b. Parts Supply Lead Time Complaints.

Apart from the problem of measuring service level parts, delays in supply of fast-moving parts due to the administrative process of waiting for PO Release with a lead time of 3 days, is also a problem for customers so it really affects the productivity of heavy equipment work. A new system is needed to provide a solution to this problem.



Figure 4.7 Flow of the Customer Parts Order Administration Process to PT. UT Sumbawa

From Figure 4.7, it can be analyzed that the supply process is slow because the lead time for issuing POs from customers takes 3 days. To analyze in more detail regarding regulations or standard operational procedures (SOP) for issuing POs from customers, analysis is carried out using Hierarchy Task Analysis (HTA) to see in detail what was done, resulting in a very long lead time and how improvements can be made (Annett, John 2000).

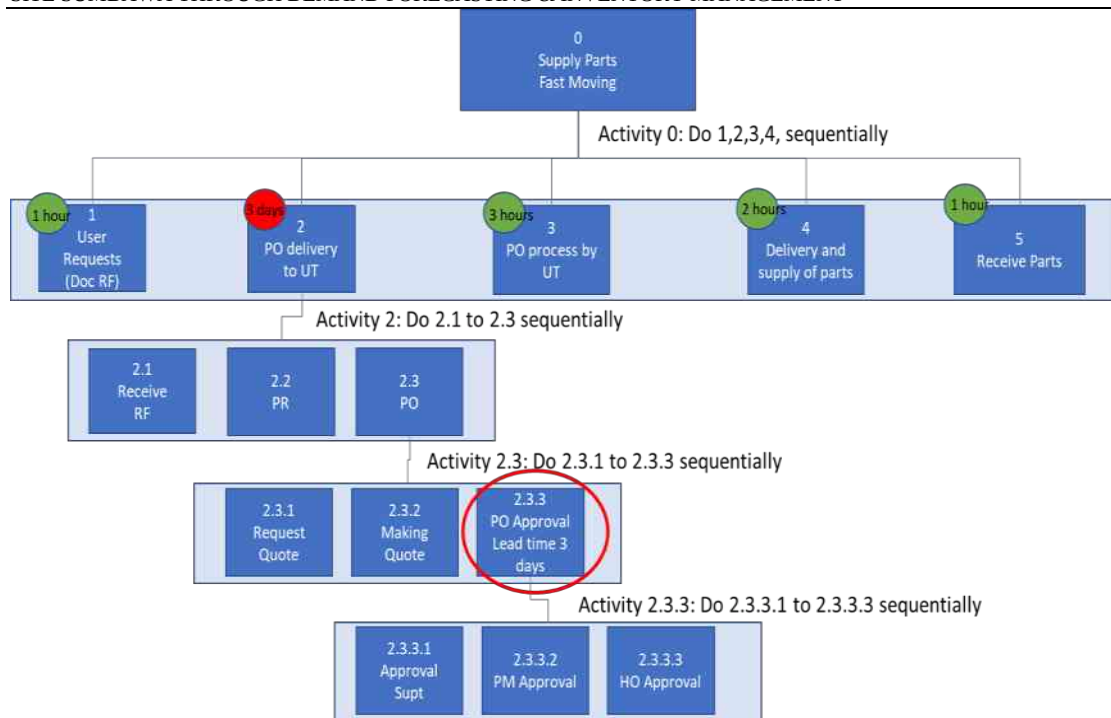


Figure 4.8 HTA Process supply parts to customer

From Figure 4.8 you can see that the SOP that must be carried out to make a PO is quite long, for this reason improvements need to be made so that the SOP does not slow down the parts supply process.

To overcome the problem of service levels that are too broad in scope and slow supply processes, researchers propose that it is necessary to limit the scope of measuring service level performance to only items that already have historical transactions in previous months. By using the Vendor Held Stock (VHS) system, which is an inventory and management system for spare parts and other materials that must be prepared and managed by the supplier. This system functions to regulate demand or stock of goods between the company and suppliers, with the hope that this can be done on time, systematically, in an organized manner with the correct quantity and quality maintained by requiring suppliers to provide several goods in the supplier's warehouse (Wahyuni Sri, 2020).

With this VHS system, the determination of items to be stocked has been mutually agreed and limited according to the agreement on the parts needed by the customer. Performance service level PT. UT Sumbawa is limited to only VHS items, and non-VHS items are excluded from measuring Service Level performance. With

the VHS system, the parts supply process can also be agreed with a new flow which can cut the supply lead time.

c. Determination and Measurement of VHS Items

To determine which items are included in the VHS, it must be adjusted to the customer's needs. AMNT asked for a guarantee of 80% Service Level in the PT warehouse. UT Sumbawa for parts that have had transactions more than 3 months a year. Based on this, the items that must be included in the VHS agreement are items that meet the minimum Month Movement criteria of 3 months. So the service level that is measured is only the service level included in the VHS item.

d. Improved parts supply speed

Based on figure 4.8 Hierarchy Task Analysis (HTA) to improve lead time supply parts, improvements need to be made in the PO manufacturing section. The researcher proposes a VHS system where there is already a supply agreement so that PO creation does not need to be done before the delivery process but is done using a collective PO pattern per VHS supply period. Spare parts supply references can use the Request Form (RF) according to the agreement between both parties.



Figure 4.9 Flow of PT's new parts order administration process. MTN to PT. UT Sumbawa

From Figure 4.9, the improvement in spare parts supply lead time, which was previously 3 days and more than 7 hours, can be accelerated to 5 hours.

4.6 Implementation & Verification

4.6.1 Implementation & Verification of Forecasting in 2023

The forecasting process from May to October 2023 has been carried out in accordance with the researcher's proposal, namely:

1. Fast Moving parts: Utilize a 12-month moving average.
2. Slow Moving parts: Utilize a 3-month moving average.

3. Error testing using the MAD method.

Then the accuracy was tested again using the MAD method and the results can be seen in table 4.30 and the graphs can be seen in figures 4.10.

Table 4.29 Comparison table of MAD error values for actual forecasting from May to October 2023.

Group	PN	12 Month Moving Average (Pcs)	6 Month Moving Average (Pcs)	3 Month Moving Average (Pcs)
Fast Moving	600-185-6110	4,88	4,97	5,44
	XS30TV	7,34	8,65	9,19
SlowMoving	207-30-00693	1,63	1,58	1,50
	56B-33-00110	0,42	0,25	0,25

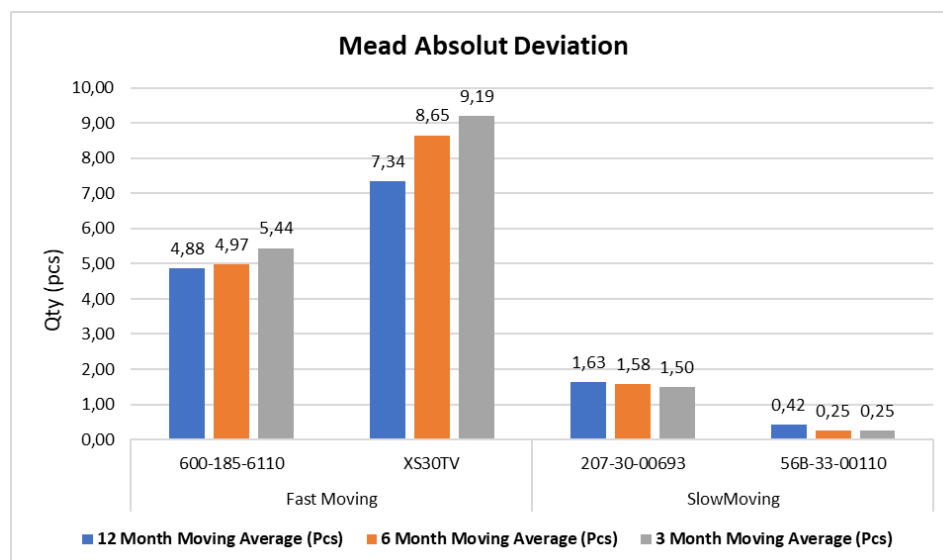


Figure 4.10 Comparison Graph of MAD error values for actual forecasting from May to October 2023.

From table 4.30 and Figure 4.10 it can be seen that the forecasting method that has been proposed is still suitable and is the most appropriate method to use in 2023.

4.6.2 Implementation & Verification of EOQ in 2023

a. Cost calculation on PN 600-185-6110

- Calculation of estimated costs without EOQ

It is known that the demand, stock order and stock data are as in table 4.30.

Table 4.30 Request, stock, and actual stock order PN 600-185-6110 without EOQ

Parts Number	Description	Not Using EOQ (Pcs)						
		Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23
600-185-6110	Demand	5	18	7	10	2	3	11
	Stock	43	38	39	56	64	76	68
	Supply	15	14	8	27	11	15	3
	Order Qty	14	8	27	11	15	3	5
	forecast	9	5	18	7	10	2	3

1 year demand (D) = 100 Pcs

Unit Price = Rp. 1,944,068 (UT purchase price to Vendor)

Number of orders in 1 year = 6 times

Average inventory = 85 Pcs

Storage costs per unit (H) = RP. 155,525 (8% from Purchase Price, Standart UT)

Cost for each Order (S) = Rp. 100,000 (Cost of each purchase to Komatsu)

Annual procurement costs = Number of orders placed per year x S = 6 x 100,000 =
 Rp. 600,000

Annual holding costs = Average inventory x H
 = 85 x 155,525 = 13,245,583

Total Actual Costs without EOQ = Rp.600,000 + Rp. 13,245,583
 = Rp. 13,845,583

- Calculation of actual cost using EOQ

Economic Order Qty (Q*) = $\frac{\sqrt{2DS}}{H} = \frac{\sqrt{2 \times 100 \times 100,000}}{155.525} = 11.34$

Number of orders in 1 year = $\frac{100}{11.34} = 9$ times

Re-order Point d = D/Quantity of months in a single year
 = 100/12 = 8.33

Safety Stock = d x Safety factor for service level 80% is 0.84
 = 9 x 0.84 = 7 Pcs

Average inventory = 50

ROP = (d x arrival time (L)) + Safety Stock
 = (8 x 1) + 7
 = 15 Pcs

Table 4.31 Request, stock, and stock order PN 600-185-6110 using EOQ.

Parts Number	Description	Using EOQ (Pcs)						
		Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23
600-185-6110	Demand	5	18	7	10	2	3	11
	Stock	16	-2	2	3	12	20	9
	Supply	11	0	11	11	11	11	0
	Order Qty		11	11	11	11		11
	forecast	9	9	9	9	10	9	8
	ROP	15						

Annual procurement costs = 0 x 100,000

= 0

Annual holding costs = 50 x 155,525

= 7,802,192

Total Cost with EOQ = Rp. 0 + Rp. 7,802,192 = Rp. 7,802,192

Efficiency using EOQ = Total cost without EOQ – Total costs with EOQ

= Rp 13,845,583 – Rp. 7,802,192

= Rp. 6,043,390

b. Cost calculation on PN XS30TV

- Calculation of estimated costs without EOQ

Table 4.32 Request, stock, and actual stock order PN XS30TV without EOQ

Parts Number	Description	Not Using EOQ (Pcs)						
		Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23
XS30TV	Demand	25	67	15	46	20	40	45
	Stock	198	153	176	230	233	262	31
	Supply	89	23	38	101	23	69	30
	Order Qty	23	38	101	23	69	30	60
	forecast	15	25	67	15	46	20	40

1 year demand (D) = 453 Pcs

Unit Price = Rp. 1,409,946 (UT purchase price to Vendor)

Number of orders in 1 year = 6 times

Average inventory = 241 Pcs

Storage costs per unit (H) = RP. 112,796 (8% from Purchase Price, Standart UT)

Cost for each Order (S) = Rp. 100,000 (Cost of each purchase to Komatsu)

Annual procurement costs = Number of orders placed per year x S = 6 x 100,000 =
Rp. 600,000

Annual holding costs = Average inventory x H

$$= 241 \times 112,796 = 27,230,757$$

$$\begin{aligned} \text{Total Actual Costs without EOQ} &= \text{Rp.}600,000 + \text{Rp. } 27,230,757 \\ &= \text{Rp. } 27,830,757 \end{aligned}$$

- Calculation of actual cost using EOQ

$$\text{Economic Order Qty (Q*)} = \frac{\sqrt{2DS}}{H} = \frac{\sqrt{2 \times 453 \times 100,000}}{112,796} = 28$$

$$\text{Number of orders in 1 year} = \frac{453}{28} = 16 \text{ times}$$

$$\begin{aligned} \text{Re-order Point d} &= D/\text{Quantity of months in a single year} \\ &= 453/12 = 37,75 \end{aligned}$$

$$\begin{aligned} \text{Safety Stock} &= d \times \text{Safety factor for service level 80\% is 0.84} \\ &= 37,75 \times 0.84 = 31,71 \text{ Pcs} \end{aligned}$$

$$\text{Average inventory} = 152$$

$$\begin{aligned} \text{ROP} &= (d \times \text{arrival time (L)}) + \text{Safety Stock} \\ &= (38 \times 1) + 31 \\ &= 69 \text{ Pcs} \end{aligned}$$

Table 4.33 Request, stock, and stock order PN XS30TV using EOQ.

Parts Number	Description	Using EOQ (Pcs)						
		Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23
XS30TV	Demand	25	67	15	46	20	40	45
	Stock	271	226	211	165	145	105	60
	Supply	89	23	0	0	0	0	0
	Order Qty	23						
	forecast	15	37	41	41	37	37	38
	ROP	69						

$$\begin{aligned} \text{Annual procurement costs} &= 0 \times 100,000 \\ &= 0 \end{aligned}$$

$$\begin{aligned} \text{Annual holding costs} &= 152 \times 112,796 \\ &= 17,144,943 \end{aligned}$$

$$\text{Total Cost with EOQ} = \text{Rp. } 0 + \text{Rp. } 17,144,943 = \text{Rp. } 17,144,943$$

$$\begin{aligned} \text{Efficiency using EOQ} &= \text{Total cost without EOQ} - \text{Total costs with EOQ} \\ &= \text{Rp } 27,830,757 - \text{Rp. } 17,144,943 \\ &= \text{Rp. } 10,685,814 \end{aligned}$$

c. Cost calculation on PN 207-30-00693

- Calculation of estimated costs without EOQ

Table 4.34 Request, stock, and actual stock order PN 207-30-00693 without EOQ

Parts Number	Description	Not Using EOQ (Pcs)						
		Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23
207-30-00693	Demand	4	2	2	5	0	0	1
	Stock	0	0	3	1	4	12	14
	Supply	0	3	6	3	3	8	3
	Order Qty	3	6	3	3	8	3	0
	forecast	2	4	2	2	5	0	0

1 year demand (D) = 20 Pcs
 Unit Price = Rp. 19,235,585 (Purchase price to Vendor)
 Number of orders in 1 year = 5 times
 Average inventory = 6 Pcs
 Storage costs per unit (H) = RP. 1,536,847 (8% from Purchase Price, Standart UT)
 Cost for each Order (S) = Rp. 100,000 (Cost of each purchase to Komatsu)
 Annual procurement costs = Number of orders placed per year x S = 5 x 100,000 =
 Rp. 500,000
 Annual holding costs = Average inventory x H
 = 6 x 1,536,847 = 8,463,657
 Total Actual Costs without EOQ = Rp.500,000 + Rp. 8,463,657
 = Rp. 8,963,657

- Calculation of actual cost using EOQ

Economic Order Qty (Q*) = $\frac{\sqrt{2DS}}{H} = \frac{\sqrt{2 \times 20 \times 100,000}}{1,538,847} = 1,61$
 Number of orders in 1 year = $\frac{10}{1,61} = 12$ times
 Re-order Point d = D/Quantity of months in a single year
 = 20/12 = 1,6
 Safety Stock = d x Safety factor for service level 80% is 0.84
 = 1,6x 0.84 = 1,4 Pcs
 Average inventory = 1,58
 ROP = (d x arrival time (L)) + Safety Stock
 = (1,6 x 1) + 1,4
 = 3Pcs

Table 4.35 Request, stock, and stock order PN 207-30-00693 using EOQ.

Parts Number	Description	Using EOQ (Pcs)						
		Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23
207-30-00693	Demand	4	2	2	5	0	0	1
	Stock	0	0	3	0	4	4	3
	Supply	0	3	6	2	4	0	0
	Order Qty	3	6	2	4			2
	forecast	2	2	3	3	3	2	2
	ROP	3						

Annual procurement costs = 7 x 100,000
= 700,000

Annual holding costs = 1,58 x 1,536,847
= 2,436,507

Total Cost with EOQ = Rp. 700,000 + Rp. 2,436,507 = Rp. 3,136,507

Efficiency using EOQ = Total cost without EOQ – Total costs with EOQ
= Rp 8,963,657 – Rp. 3,136,507
= Rp. 5,827,150

d. Cost calculation on PN 56B-33-00110

- Calculation of estimated costs without EOQ

Table 4.36 Request, stock, and actual stock order PN 56B-33-00110

Parts Number	Description	Not Using EOQ (Pcs)						
		Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23
56B-33-00110	Demand	0	0	0	0	1	0	2
	Stock	9	9	9	9	8	8	8
	Supply	0	0	0	0	0	0	2
	Order Qty	0	0	0	0	0	2	0
	forecast	0	0	0	0	0	1	0

1 year demand (D) = 3 Pcs

Unit Price = Rp. 12,757,115 (UT purchase price to Vendor)

Number of orders in 1 year = 1 times

Average inventory = 9 Pcs

Storage costs per unit (H) = RP. 1,020,569 (8% from Purchase Price, Standart UT)

Cost for each Order (S) = Rp. 100,000 (Cost of each purchase to Komatsu)

Annual procurement costs = Number of orders placed per year x S = 1 x 100,000 =
Rp. 100,000

$$\begin{aligned}\text{Annual holding costs} &= \text{Average inventory} \times H \\ &= 9 \times 1,020,569 = 9,185,123 \\ \text{Total Actual Costs without EOQ} &= \text{Rp. } 100,000 + \text{Rp. } 9,185,123 \\ &= \text{Rp. } 9,285,123\end{aligned}$$

- Calculation of actual cost using EOQ

$$\begin{aligned}\text{Economic Order Qty (Q*)} &= \frac{\sqrt{2DS}}{H} = \frac{\sqrt{2 \times 3 \times 100,000}}{1,020,569} = 0,8 \\ \text{Number of orders in 1 year} &= \frac{3}{0,8} = 4 \text{ times} \\ \text{Re-order Point d} &= D/\text{Quantity of months in a single year} \\ &= 3/12 = 0,25 \\ \text{Safety Stock} &= d \times \text{Safety factor for service level 80\% is 0.84} \\ &= 0,25 \times 0.84 = 0,21 \text{ Pcs} \\ \text{Average inventory} &= 9 \\ \text{ROP} &= (d \times \text{arrival time (L)}) + \text{Safety Stock} \\ &= (0,25 \times 1) + 0,21 \\ &= 0,46 \text{ Pcs}\end{aligned}$$

Table 4.37 Request, stock, and stock order PN 56B-33-00110 using EOQ.

Parts Number	Description	Using EOQ (Pcs)						
		Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23
56B-33-00110	Demand	0	0	0	0	1	0	2
	Stock	9	9	9	9	8	8	6
	Supply	0	0	0	0	0	0	0
	Order Qty	0	0	0	0	0	0	0
	forecast	0	0	0	0	0	1	1
	ROP	0						

$$\begin{aligned}\text{Annual procurement costs} &= 0 \times 100,000 \\ &= 0 \\ \text{Annual holding costs} &= 9 \times 1,020,569 \\ &= 9,185,123 \\ \text{Total Cost with EOQ} &= \text{Rp. } 0 + \text{Rp. } 9,185,123 = \text{Rp. } 9,185,123 \\ \text{Efficiency using EOQ} &= \text{Total cost without EOQ} - \text{Total costs with EOQ} \\ &= \text{Rp } 9,285,123 - \text{Rp. } 9,185,123 \\ &= \text{Rp. } 100,000\end{aligned}$$

Of the four products that have been simulated by comparing the actual order process and the EOQ method, results are obtained as in table 4.38.

Table 4.38 Comparison of 2023 Costs between without and with EOQ.

Description	Parts Number							
	600-185-6110		XS30TV		207-30-00693		56B-33-00110	
	Without EOQ	With EOQ	Without EOQ	With EOQ	Without EOQ	With EOQ	Without EOQ	With EOQ
Q*		11		28		1,6		0,8
Procurement Cost (Rp)	600.000	0	600.000	0	500.000	700.000	100.000	0
Storage Cost (Rp)	13.245.583	7.802.193	27.230.757	17.144.943	8.463.657	2.436.507	9.185.123	9.185.123
Total Cost (Rp)	13.845.583	7.802.193	27.830.757	17.144.943	8.963.657	3.136.507	9.285.123	9.185.123
Efisiensi with EOQ	6.043.390		10.685.814		5.827.150		100.000	

From table 4.39 with EOQ you will get cheaper costs than processing orders without using EOQ.

4.6.3 Evaluation of DOI & Stock Amount Performance in 2022

After implementing forecasting and inventory control methods according to researchers' recommendations, figures 4.11 and 4.12 are the achievements of DOI and Stock Amount in 2023.

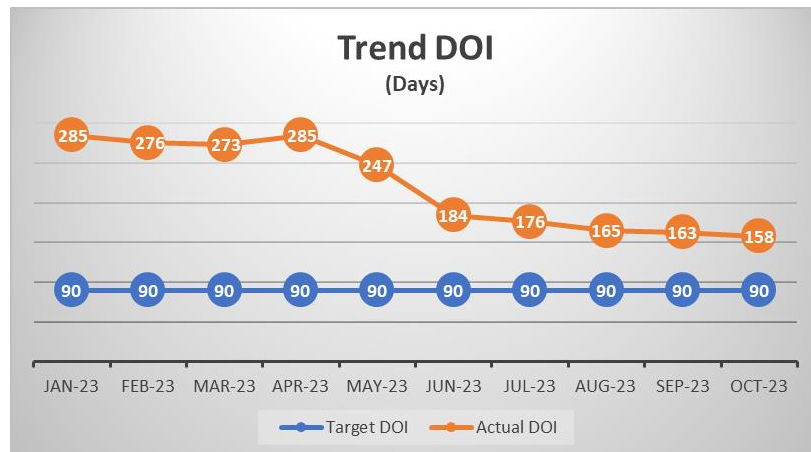


Figure 4.11 DOI Performance Trend

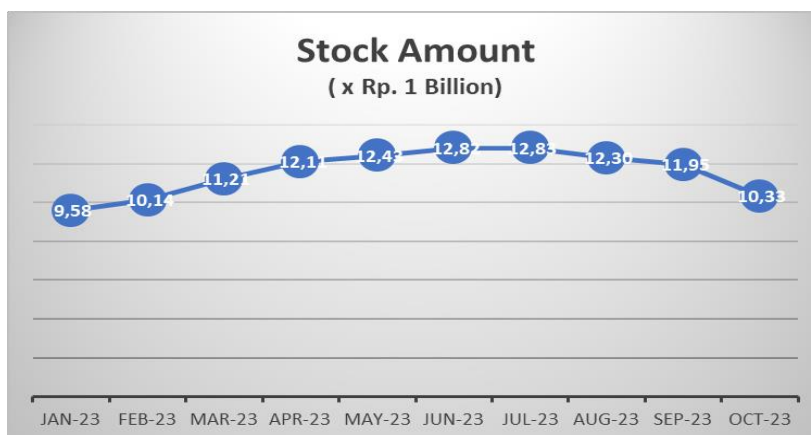


Figure 4.12 Trend Stock Amount

4.7.4 Evaluation of Service Level Performance in 2023

After implementing forecasting and inventory control methods according to researchers' recommendations, Figure 4.13 is the achievement of service level in 2023.



Figure 4.13 Service Level Trend in 2023

4.7 Control Management

Management Control in this research is carried out in 4 ways, namely:

1. Creation and implementation of Standard Operational Procedures (SOP) Order Process & Inventory Management at PT. UT Sumbawa.
2. Monthly Review Achievement Performance by PT management. UT Sumbawa.
3. Create a standard check list for order processing & inventory management procedures.
4. Regular Audit Procedures Order Process & Inventory Management.

Tabel 4.39 Inventory Procedure Audit Checklist and order process

Check the Inventory Management & Purchase Order Audit List

Audit	No	Activity	Evident	PIC	YES	NO
People	1	Regular Training Parts Book Reading	Implementation Schedule & Attendance	Mechanic, COP & ASC		
	2	Coaching from Supervisor/Management	Personal Contact Form	Supervisor		
	3	Daily Morning Meeting	Absensi, MoM	All Team Parts Dept		
	4	Performance Review	Schedule, Attendance, MoM	All Team Parts Dept		
Proses	1	Implementation of Metode Forecasting	Forecasting calculation data	PSC		
	2	Implementation of Reorder Point	Purchase order calculation data	PSC		
	3	Implementation of EOQ	Purchase order calculation data	PSC		
	4	Supervision & Validation of Parts Recommendations	Recommendation Approval Form	Supervisor		
	5	Supervision & Validation of Quotation Parts	Quotation and Approval Files	Supervisor		
Infrastruktur	1	Parts Book	Parts Book is in good condition	Mechanic/Technician		
	2	Computer and parts book files	Computer condition is good	PTO & COP		
	3	Standard Recommendation Form	Stock Form	GA		