

DETERMINING DEMAND FORECASTING AND INVENTORY POLICY FOR MANAGEMENT OF RAW MATERIALS WITH ENGINEERING TO ORDER CHARACTERISTICS IN THE ELECTRICITY MAINTENANCE INDUSTRY

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Abstract:

This study examines the optimization of critical raw material inventory control policies in an Engineering-to-Order (ETO) manufacturing unit operating under a "no inventory" policy. The main challenges in the ETO system are demand uncertainty and unique product specifications, which are exacerbated by the prohibition on stocking. Through ABC analysis and CV-ADI classification, three critical materials (Materials 1, 4, and 7) are identified with lumpy and erratic demand patterns. The Syntetos-Boylan Approximation (SBA) forecasting method proves to be the most accurate for these demand patterns. Furthermore, three inventory policy scenarios (existing, continuous review (s, Q), and periodic review (R, S)) are evaluated based on total cost and service level. The results show that the existing policy has a low service level. For Materials 1 and 7, the continuous review (s, Q) system offers the most optimal cost with high service levels (77.14% and 95.30%). Meanwhile, for Material 4, the periodic review (R, S) system proves to be the most efficient with a service level of 95%. This study provides data-driven inventory policy recommendations that can improve operational efficiency, minimize stockout risks, and support production sustainability in an ETO environment with inventory constraints.

Keywords: Engineering-to-Order (ETO), Inventory Control, Critical Raw Materials, Demand Forecasting, Syntetos-Boylan Approximation (SBA), Continuous Review, Periodic Review, Service Level.

INTRODUCTION

Manufacturing industries with an Engineering-to-Order (ETO) production model face unique challenges in supply chain management, particularly in the planning and procurement of raw materials. In an ETO system, each product is designed and manufactured based on different technical specifications according to customer requirements (Radke & Tseng, 2012). It leads to high uncertainty in the material requirements planning process and production timelines.

One manufacturing unit implementing the ETO system is the Electricity Maintenance Unit, which is under the national energy sector's parent company. This unit is responsible for fulfilling the reverse engineering, repair, and manufacturing needs of electrical components in generation, transmission, and distribution systems. The entire production process is customized and cannot be mass-produced, thus heavily dependent on accurate material planning.

From 2021 to 2024, this unit saw a significant increase in the value of assignments. The value of assignments grew from Rp239 billion in 2021 to Rp806 billion in 2023, with a target of Rp1.5 trillion by 2024.





Figure 1. Electrical Maintenance Unit Assignment Values for 2021 - 2024

Most assignments come from the generation sector, as shown in the following table.

Table 1. Values per Assignment Category

Assignment Type	Year 2023			Year 2024 (per Oktober)		
	Amount	Mark	Percentage	Amount	Mark	Percentage
Generation	373	436.172.663.025	54,12%	868	865.008.656.053	85,76%
Distribution	76	296.726.711.396	36,81%	133	135.154.528.097	13,40%
Etc	29	73.082.533.579	9,07%	46	3.599.927.478	0,36%
Transmission	1	18.092.000	0,002%	28	4.920.675.550	0,49%
Amount	479	806.000.000.000		1075	1.008.683.787.178	

The level of delay in completing assignments is an indicator of systemic problems in managing material demand and supply.

Table 2. Electrical Maintenance Unit Work Completion Data (Value in Million Rupiah)

Completion of Assignment	2024 (Per July)		2023		2022		Average Percentage
	Mark	Percentage	Mark	Percentage	Mark	Percentage	
On time	330,535	77,74%	521,208	86,23%	224,055	78,76%	81,87%
Late and Amendments	94,633	22,26%	83,215	13,77%	60,426	21,24%	18,13%
≤ 100 days	42.616	45,03%	38.463	46,22%	53.133	87,93%	
101- 200 days	4.590	4,85%	34.700	41,70%	7.293	12,07%	
201 - 300 days	5.820	6,15%	10.053	12,08%	-	-	
> 300 days	41.608	43,97%	-	-	-	-	
Amount	425,169		604,424		284,481		

The increasing number of delayed jobs is closely related to delays in material supply. The no-inventory regulations in place in this unit add to the challenge because raw materials cannot be stored until an official assignment has been granted. Therefore, accurate material requirements forecasting is critical.

To anticipate supply delays, the unit implemented a Unit Price Contract (KHS) system with suppliers. However, this system remained ineffective because material quotas in the KHS often did not match actual needs, leading to backlogs and production delays.



Table 3. Quota Volume and KHS Realization

No	Material	Job Category	Sat	Vol Quota	Contract Value (Rupiah)	Vol Realization	Realized Value (Rupiah)	Volume Difference	Realization
1	Material 1	Generation	Kg	40.000	97.680.000.000	80.608	196.844.736.000	-40.608	-102%
	Material 2-1		Set	1.770	3.782.047.500	1.180	2.521.365.000	590	33%
2	Material 2-2	Distribution	Set	1.770	6.257.569.500	1.180	4.171.713.000	590	33%
	Material 2-3		Set	870	7.339.320.000	580	4.892.880.000	290	33%
	Material 2-4		Pcs	3.540	8.644.680.000	2.360	5.763.120.000	1.180	33%
3	Material 3	Distribution	Unit	200	8.702.400.000	265	11.530.680.000	-65	-33%
4	Material 4	Generation	Kg	10.000	765.900.000	129.003	9.880.339.770	-119.003	-1190%
5	Material 5-1	Distribution	Unit	20	9.379.500.000	13	6.096.675.000	7	35%
	Material 5-2		Unit	8	5.455.872.000	5	3.409.920.000	3	38%

The discrepancy between quota and actual performance indicates a significant gap in the planning system. A significant difference in actual performance indicates a suboptimal demand forecasting process within the unit.

Without accurate forecasting methods, suppliers cannot stock raw materials on time. It is a major source of delays in material supply, which ultimately results in delayed product delivery to the customer.

With this background, this research is focused on:

1. Design a more accurate method for forecasting critical raw material demand.
2. Develop an inventory policy that aligns with the characteristics of the ETO system and the limitations of inventory.

METHODS

This study uses a descriptive quantitative approach to formulate a material requirements planning strategy and inventory policy in the Engineering to Order (ETO) system in the Electrical Maintenance Unit. The study was conducted in systematic stages, including historical data collection, material classification, demand forecasting, and inventory policy simulation.

Research Design. This research began with a background analysis of the unit and the collection of historical data on raw material demand and usage. It was followed by an analysis of critical material classification, selection of the most accurate forecasting method, and calculation of inventory policy simulations.

Data Collection. Data was obtained from the internal documentation of the electrical maintenance unit, including:

- Demand History: Raw material usage data for the period January 2021 – April 2025.
- Unit Price Contract (KHS) Data: Details of contract value, quota volume, and actual usage.
- Material Lead Time: Average waiting time from ordering to receiving materials.

Material Classification. Materials are grouped using two methods:

- ABC analysis to identify materials with the highest value contribution (category A).
- ADI-CV classification to determine demand patterns: smooth, intermittent, lumpy, or irregular.

Materials with a cumulative value contribution of $\geq 80\%$ are categorized as critical materials.

Demand Forecasting Methods. Four forecasting methods were tested and compared based on error values:



1. Regression Linear
2. Double Exponential Smoothing (Holt's)
3. Winter's Model
4. Syntetos-Boylan Approximation (SBA)

The selection of the best method is based on the minimum error results using the Mean Absolute Percentage Error (MAPE).

Table 4. Scenario Design

Scenario	Inventory System	Object
Existing	<i>Existing Inventory with No Inventory system in the unit electrical maintenance, using the Contracts Unit Price (Inventory at the material supplier)</i>	Sample from selected classification
1	<i>Continuous Review (s, Q System)</i>	results
2	<i>Periodic Review and Order Up to Level (R, S system)</i>	

RESULT AND DISCUSSION

This section presents the results of the analysis and interpretation of data carried out to identify critical raw material requirements and formulate optimal inventory policies for the Electrical Maintenance Unit.

Demand History. Historical demand data from January 2021 to April 2025 were collected for Materials 1, 4, and 7, which are critical materials in the power generation sector.

- Material 1: Total requirement: 213,656 kg. Unit price varies (Rp 132,700 - Rp 250,322), differing from the KHS (Rp 170,000), indicating the use of separate contracts.
- Material 4: Total requirement: 1,639,012 kg. Unit price varies (Rp 12,739 - Rp 100,538), differing from the KHS (Rp 56,750).
- Material 7: Total requirement: 463,617 kg. Unit price varies (Rp 51,262 - Rp 279,646), differing from the KHS (Rp 107,900).

Raw Material Lead Time.

- Material 1: 30 calendar days
- Material 4: 10 calendar days
- Material 7: 30 calendar days

Classification of Raw Materials with ABC Analysis. Of the 35 material groups, 8 groups are classified as Category A (critical materials), contributing 81.76% of the total contract realization value. This study focuses on 3 critical materials from the generation category: Material 1, Material 4, and Material 7.

Table 5. Material Classification Based on ABC Analysis

No	Material	Value (in Rp Million)	% Mark	% Cumulative	Category
1	Material 1	98.288	47,80%	47,80%	A
2	Material 2	17.309	8,42%	56,22%	A
3	Material 3	11.531	5,61%	61,83%	A
4	Material 4	9.880	4,81%	66,63%	A
5	Material 5	9.507	4,62%	71,25%	A
6	Material 6	8.565	4,17%	75,42%	A
7	Material 7	7.005	3,41%	78,83%	A



8	Material 8	6.035	2,94%	81,76%	A
9	Material 9	5.694	2,77%	84,53%	B
10	Material 10	4.198	2,04%	86,57%	B
11	Material 11	3.299	1,60%	88,18%	B
12	Material 12	2.617	1,27%	89,45%	B
13	Material 13	2.335	1,14%	90,59%	B
14	Material 14	2.245	1,09%	91,68%	C
15	Material 15	2.101	1,02%	92,70%	C
16	Material 16	2.049	1,00%	93,70%	C
17	Material 17	1.687	0,82%	94,52%	C
18	Material 18	1.661	0,81%	95,32%	C
19	Material 19	1.587	0,77%	96,10%	C
20	Material 20	1.307	0,64%	96,73%	C
21	Material 21	1.304	0,63%	97,37%	C
22	Material 22	1.264	0,61%	97,98%	C
23	Material 23	883	0,43%	98,41%	C
24	Material 24	718	0,35%	98,76%	C
25	Material 25	666	0,32%	99,08%	C
26	Material 26	647	0,31%	99,40%	C
27	Material 27	492	0,24%	99,64%	C
28	Material 28	403	0,20%	99,83%	C
29	Material 29	265	0,13%	99,96%	C
30	Material 30	77	0,04%	100,00%	C
31	Material 31	-	0,00%	100,00%	C
32	Material 32	-	0,00%	100,00%	C
33	Material 33	-	0,00%	100,00%	C
34	Material 34	-	0,00%	100,00%	C
35	Material 35	-	0,00%	100,00%	C

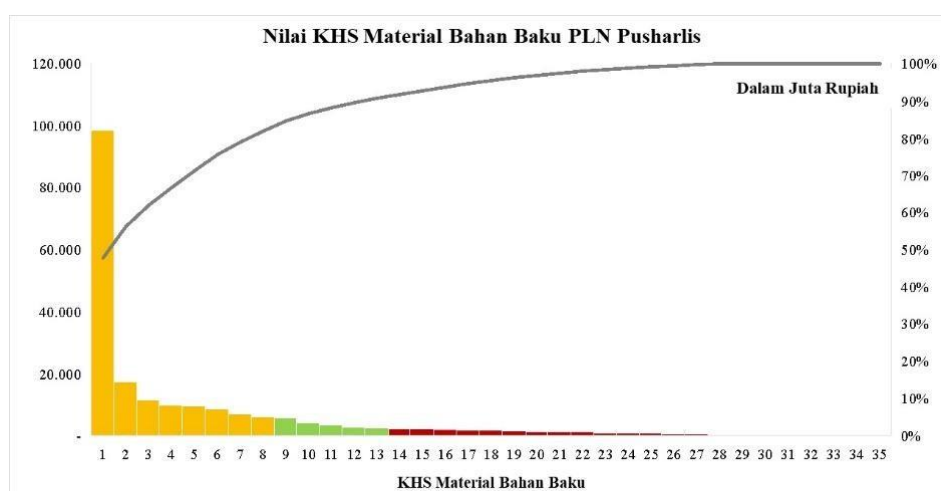


Figure 2. Pareto Diagram of KHS Value of Raw Materials

Calculation of Coefficient of Variance (CV) and Average Demand Interval (ADI). The demand pattern of sample materials is analyzed using CV and ADI.

- Material 1: CV = 0,896; ADI = 2,476. Classification: Lumpy.
- Material 4: CV = 2,275; ADI = 1,857. Classification: Lumpy.



- Material 7: CV = 1,529; ADI = 1,238. Classification: Erratic.

Table 6. CV – ADI Classification and Recommended Forecast Methods

No	Name Material	CV	CV ²	ADI	CV – ADI Classification	Recommended Methods Forecast (Syntetos, et al., 2005)
1	Material 1	0,896	0,802	2,476	Lumpy	Syntetos – Boylan Approximation
2	Material 4	2,275	5,175	1,857	Lumpy	Syntetos – Boylan Approximation
3	Material 7	1,529	2,339	1,238	Erratic	Syntetos – Boylan Approximation

Based on this classification, the Syntetos-Boylan Approximation (SBA) method is recommended for forecasting all three materials due to their lumpy and erratic demand characteristics.

Raw Material Demand Forecast. Forecasting is performed using Linear Regression, Double Exponential Smoothing, Winter's Model, and SBA. MAPE, MAD, and MSE measure accuracy.

Table 7. Results of Material Forecasting Accuracy Test 1

Error	Regression Linear	Double Exponential Smoothing	Winter's Method	Syntetos–Boylan Approximation
MAPE	91	191	158	78,75
MAD	5.446	6.533	6.205	4.933,24
MSE	42.527.508	72.153.520	53.496.155	44.195.089,92

Based on Table 7, the forecasting method for Material 1 that produced the best forecasting accuracy test used the Syntetos–Boylan Approximation method. The results of the demand forecast for Material 1 using the Syntetos–Boylan Approximation method are as follows:

Table 8. Material Forecasting Results 1

No	Month	Forecast Results (kg)	Price per kg (Rp)	Total Price (Rp)
1	May 2025	2.844	170.000	483.480.000
2	Jun 2025	2.844	170.000	483.480.000
3	Jul 2025	2.844	170.000	483.480.000
4	Aug 2025	2.844	170.000	483.480.000
5	Sep 2025	2.844	170.000	483.480.000
6	Oct 2025	2.844	170.000	483.480.000
7	Nov 2025	2.844	170.000	483.480.000
8	Dec 2025	2.844	170.000	483.480.000
9	Jan 2026	2.844	170.000	483.480.000
10	Feb 2026	2.844	170.000	483.480.000
11	Mar 2026	2.844	170.000	483.480.000
12	Apr 2026	2.844	170.000	483.480.000
Total cost				5.801.760.000



Based on Table 8, the total costs that must be incurred to meet the needs of Material 1 for 12 periods, with the amount of material following the forecast results, are 5,801,760,000 Rupiah.

Table 9. Results of Material Forecasting Accuracy Test 4

Error	Regression Linear	Double Exponential Smoothing	Winter's Method	Syntetos-Boylan Approximation
MAPE	397	1.782	1.126	206,59
MAD	9.816	12.409	15.060	8.367,52
MSE	531.686.164	860.259.967	634.958.759	547.083.897,31

Based on Table 9, the forecast method for Material 4 that produces the best forecast accuracy test uses the Syntetos-Boylan Approximation method. The results of the demand forecast for Material 4 using the Syntetos-Boylan Approximation method are as follows:

Table 10. Material Forecasting Results 4

No	Month	Forecast Results (kg)	Price per kg (Rp)	Total Price (Rp)
1	May 2025	4.478	56.750	254.126.500
2	Jun 2025	4.478	56.750	254.126.500
3	Jul 2025	4.478	56.750	254.126.500
4	Aug 2025	4.478	56.750	254.126.500
5	Sep 2025	4.478	56.750	254.126.500
6	Oct 2025	4.478	56.750	254.126.500
7	Nov 2025	4.478	56.750	254.126.500
8	Dec 2025	4.478	56.750	254.126.500
9	Jan 2026	4.478	56.750	254.126.500
10	Feb 2026	4.478	56.750	254.126.500

Based on Table 10, the total cost that must be incurred to meet the needs of Material 4 for 12 periods, with the amount of material following the forecast results, is 3,049,518,000 Rupiah.

Table 11. Results of Material Forecasting Accuracy Test 7

Error	Regression Linear	Double Exponential Smoothing	Winter's Method	Syntetos-Boylan Approximation
MAPE	656	852	836	369,22
MAD	9.617	12.317	10.281	8.381,4
MSE	230.441.356	436.638.765	226.234.601	260.430.722,05

Based on Table 11, the forecasting method for Material 7 that yielded the best forecasting accuracy was the Syntetos-Boylan Approximation method. The demand forecast results for Material 7 using the Syntetos-Boylan Approximation method are as follows:

Table 12. Material Forecasting Results 7

No	Month	Forecast Results (kg)	Price per kg (Rp)	Total Price (Rp)
1	May 2025	4.525	51.262	231.960.550
2	Jun 2025	4.525	51.262	231.960.550



3	Jul 2025	4.525	51.262	231.960.550
4	Aug 2025	4.525	51.262	231.960.550
5	Sep 2025	4.525	51.262	231.960.550
6	Oct 2025	4.525	51.262	231.960.550
7	Nov 2025	4.525	51.262	231.960.550
8	Dec 2025	4.525	51.262	231.960.550
9	Jan 2026	4.525	51.262	231.960.550
10	Feb 2026	4.525	51.262	231.960.550

Based on Table 12, the total cost that must be incurred to meet the needs of Material 7 for 12 periods, with the amount of material following the forecast results, is 2,783,526,600 Rupiah.

Inventory Policy Calculation, Inventory Cost Components.

- Purchasing Cost: Based on KHS (Material 1: Rp 170,000/kg; Material 4: Rp 56,750/kg; Material 7: Rp 51,262/kg).
- Ordering Cost: Total Rp 108,404 per transaction (including electricity, administration, internet, salaries, and assets).
- Holding Cost: Rate 23% of the material price per unit per year.
- Stockout Cost: Penalty of 1/1000 of the material value per delay.

Determining Service Levels with Financial Value. A 100% service level is calculated based on a 10% risk buffer of the total assignment target. If the 2025 target is IDR 2 trillion, the financial value for a 100% service level is IDR 200 billion.

Existing Inventory Scenario. The existing policy uses KHS with no inventory policy.

- Material 1: Total simulation cost Rp 1,300,848. With the service level gap (49.62% SL) elaboration, the total cost becomes Rp 293,576,888.
- Material 4: Total simulation cost Rp 1,300,848. With the service level gap (7.75% SL) elaboration, the total cost becomes Rp 282,613,523.
- Material 7: Total simulation cost Rp 1,300,848. With the service level gap (85.83% SL) elaboration, the total cost becomes Rp 40,753,481.

Continuous Review (s, Q System). Multi-run simulations are performed to optimize the parameters (s, Q).

- Material 1: Optimal at s=3200, Q=3500. Total cost Rp 144,246,536 (77.14% SL).
- Material 4: Optimal at s=1706, Q=4300. Total cost Rp 103,569,883 (92.03% SL).
- Material 7: Optimal at s=4899, Q=3000. Total cost Rp 20,811,645 (95.30% SL).

Periodic Review and Order Up to Level (R, S System). Simulations were conducted with varying review periods (R) and service levels.

- Material 1: Optimal at R=1 month, 95% SL. Total cost Rp 157,439,898.
- Material 4: Optimal at R=1 month, 95% SL. Total cost Rp 79,479,688.
- Material 7: Optimal at R=1 month, 95% SL. Total cost Rp 76,766,102.

Recapitulation of Total Cost and Service Level Inventory Policy. Each method used aims to identify the most efficient inventory management policy, taking into account cost, lead time, and desired service level. In this context, the targeted service level is 95%, but still reflects the most optimal cost level.

Table 13. Summary of Total Costs and Service Level Inventory Policy



	Existing		Continuous Review (s, Q System)		Periodic Review and Order Up to Level (R, S)	
	Total cost	Service Level	Total cost	Service Level	Total cost	Service Level
Material 1	293.576.888	49,62%	144.246.536	77,14%	157.439.898	95%
Material 4	282.613.523	7,75%	103.569.883	92,03%	79.479.688	95%
Material 7	40.753.481	85,83%	20.811.645	95,30%	76.766.102	95%

Based on Table 14, the inventory policy chosen based on the most optimal cost for Material 1 is to use continuous review (s, Q System) with a total cost of 144,246,536 Rupiah, Material 2 with periodic review and order up to level (R, S) with a total cost of 79,479,688 Rupiah, and Material 7 with the continuous review method (s, Q System) with a total cost of 20,811,645 Rupiah.

Data Analysis and Interpretation.

Material Classification Analysis (ABC & CV-ADI). Material classification using ABC analysis showed that 8 of the 35 material groups were critical (Category A), accounting for 81.76% of the total contract value. Four Category A materials had usage volumes exceeding the KHS contract quota, indicating inaccurate planning and contributing to supply delays.

The CV-ADI analysis of Materials 1 and 4 shows a lumpy demand pattern, characterized by infrequent but large-quantity demand. Material 7 exhibits an erratic pattern, with highly fluctuating and irregular demand. These patterns highlight the need for adaptive forecasting methods and inventory policies, rather than traditional methods that assume stable demand. The recommendation to use SBA for forecasting is based on its ability to handle intermittent and lumpy demand patterns better.

Material Forecasting Analysis. The results of the forecasting method comparison show that the Syntetos-Boylan Approximation (SBA) consistently produces the lowest error values (MAPE, MAD, MSE) for Materials 1, 4, and 7. It confirms that SBA is more suitable for the lumpy and erratic demand patterns found in critical materials in the Electrical Maintenance Unit. Higher forecasting accuracy from SBA will be a strong basis for more precise material requirements planning, reduce the risk of stockouts or excess stock, and support procurement budget efficiency.

Inventory Policy and Service Level Analysis per Material.

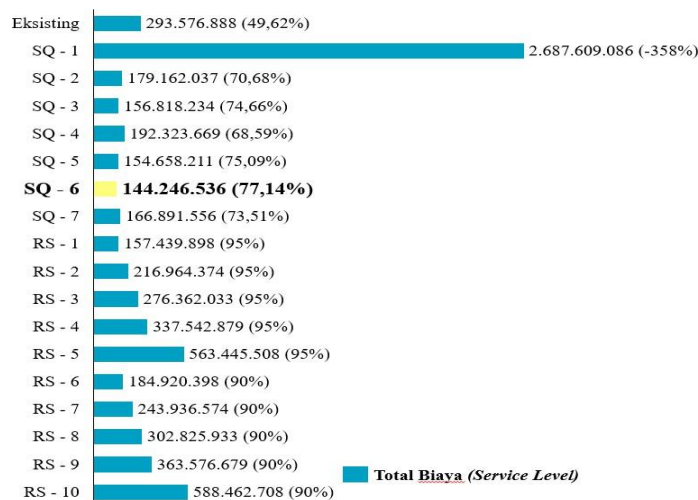


Figure 3. Results of the Recapitulation of Total Inventory Policy Costs with Elaboration of Service Level Material 1 Values

Material 1.

- Existing Policy: Costs Rp 293,576,888 with a service level of only 49.62%. It indicates very poor performance and a high risk of stockouts, which can lead to project delays and penalties.
- Continuous Review (s, Q): Offers the most optimal solution with a cost of Rp 144,246,536 and a service level of 77.14%. While not yet reaching 90%, this is a significant improvement over the existing condition with a much lower cost. Sensitivity to the (s, Q) parameter needs to be considered.
- Periodic Review (R, S): Achieves a service level of 95% at a cost of Rp 157,439,898. It costs more than the optimal continuous review but provides higher service reliability, suitable for highly critical materials.

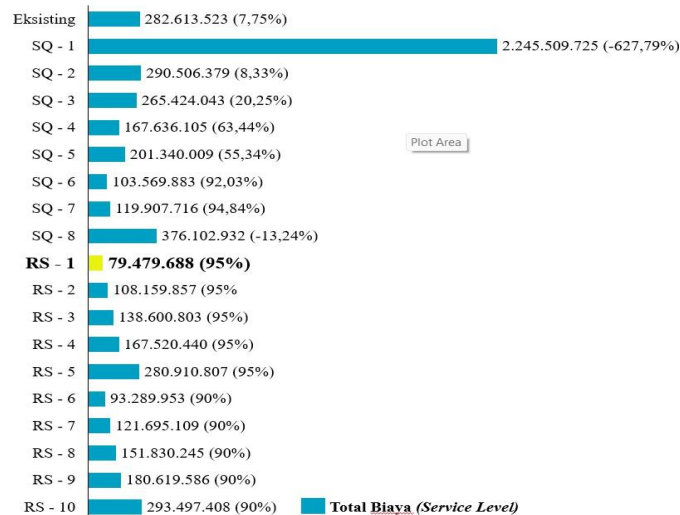


Figure 4. Results of the Recapitulation of Total Inventory Policy Costs with Elaboration of Service Level Values for Material 4

Material 4.

- Existing Policy: Cost of Rp 282,613,523 with a very low service level of only 7.75%. It demonstrates the inability of the existing system to meet the demand for this material.
- Continuous Review (s, Q): Achieved a service level of 92.03% at a cost of Rp 103,569,883. It represents a significant improvement in service and cost efficiency compared to the existing policy.
- Periodic Review (R, S): The most efficient option with a cost of Rp 79,479,688 and a service level of 95%. It demonstrates that for Material 4, the periodic review approach can provide the best balance between cost and high service levels.



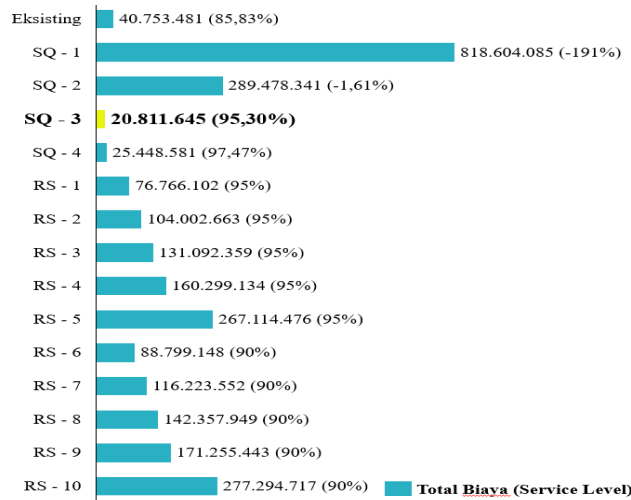


Figure 5. Results of the Recapitulation of Total Inventory Policy Costs with Elaboration of Service Level Values for Material 7

Material 7.

- Existing Policy: Costs Rp 40,753,481 with a service level of 85.83%. While better than Materials 1 and 4, there is still room for improvement towards the ideal target.
- Continuous Review (s, Q): Offers the most optimal solution at a cost of Rp 20,811,645 and a service level of 95.30%. It is a significant improvement in service with a drastic reduction in costs.
- Periodic Review (R, S): Achieves a service level of 95% at a cost of Rp 76,766,102. While effective in achieving high service, the cost is higher than the optimal continuous review for this material.

Inventory Policy Analysis Conclusion. There is a clear trade-off between total inventory cost and service level. The existing policy is inadequate for critical materials. Continuous Review (s, Q) offers high cost efficiency with good service potential if parameters are properly calibrated. Periodic Review (R, S) provides higher service stability, suitable for materials with intolerable critical risk, although at a potentially higher cost. The optimal policy selection must consider the specific characteristics of the material and stockout risk tolerance.

CONCLUSION

1. Material Classification: Through ABC Analysis, 8 of 35 material groups were identified as critical (Category A), accounting for 81.76% of the contract value. Four of these exceeded the contract quota, indicating a need for improved planning. CV-ADI analysis revealed lumpy (Materials 1 & 4) and erratic (Material 7) demand patterns, requiring adaptive control strategies.
2. Demand Forecasting: The Syntetos-Boylan Approximation (SBA) method consistently produced the lowest errors (MAPE, MAD, MSE) for all three sample materials, making it the most suitable forecasting method for irregular demand patterns.
3. Existing Inventory Policy: Indicates moderate inventory costs but low service levels (Materials 1 & 4) or relatively good but not optimal (Material 7), indicating an urgent need for improvement.
4. Continuous Review (s, Q System): Offers the potential for high cost efficiency with service levels reaching ≥90–95% if parameters are properly calibrated. However, this method is very sensitive to parameter setting errors.



5. Periodic Review (R, S System): Allows for more consistent service level settings at 90–95%, but tends to incur higher costs. This method is suitable for highly critical materials where the risk of stockouts is intolerable.
6. Cost vs. Service Trade-off: There is a clear trade-off between total inventory costs and service levels. Policy selection should be based on the demand characteristics and risk profile of each material.
7. Optimal Recommendations:
 - For Materials 1 and 7, the Continuous Review (s, Q System) system proved to be the most cost-optimal while achieving good service levels (77.14% for Material 1 and 95.30% for Material 7).
 - For Material 4, the Periodic Review and Order Up to Level (R, S System) system was the most efficient, with the lowest costs and a service level of 95%.

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