



OPTIMIZING MAINTENANCE INVENTORY MANAGEMENT TO IMPROVE OPERATIONAL EFFICIENCY, ASSET RELIABILITY AND FINANCIAL PERFORMANCE

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Abstract: This study investigates the root causes of slow-moving and non-moving maintenance inventory accumulation and develops an integrated inventory optimization framework to improve inventory turnover while maintaining asset reliability. A convergent mixed-methods case study was conducted at PT Pertamina Patra Niaga–Refinery Operations Directorate (PT PPN), combining semi-structured interviews with cross-functional stakeholders and quantitative inventory analysis using an integrated ABC–VED–FSN classification approach. The findings reveal five interconnected root causes of inventory inefficiency, including the absence of criticality-based inventory segmentation, poor master data quality, inadequate inventory review mechanisms, disposal governance constraints, and conservative procurement planning practices. The study proposes a differentiated inventory treatment strategy integrated with Reliability-Centered Spare Parts (RCSP) principles, enabling organizations to distinguish between strategically justified inventory and inefficient stock accumulation. The proposed framework contributes to the maintenance inventory management literature by integrating inventory value, movement behavior, operational criticality, and reliability considerations within a single decision-making model. Managerially, the framework provides a practical roadmap for improving inventory turnover, reducing provisioning exposure, releasing working capital, and strengthening inventory governance without compromising operational continuity. The results offer valuable insights for refinery operations and other asset-intensive industries facing similar inventory optimization challenges.

Keywords (English): maintenance inventory management, inventory turnover ratio, ABC-VED-FSN classification, slow-moving inventory, provisioning

INTRODUCTION:

The oil refining industry is one of the most capital-intensive industrial sectors in the world. Refinery operations are fundamentally dependent on the reliability of physical assets, encompassing stationary equipment, rotating machinery, electrical systems, and instrumentation (Ajenifuja, 2024). Failure in any of these asset components has the potential to trigger unplanned downtime, resulting in large-scale production losses, safety hazards, and significant financial consequences (Gidiagba et al., 2023). Consequently, maintaining asset reliability while sustaining operational efficiency constitutes a strategic priority that cannot be compromised in refinery management (Ohalete et al., 2024).

One of the critical pillars supporting both objectives is maintenance inventory management, particularly for Maintenance, Repair, and Operations (MRO) materials. The timely availability of spare parts is a prerequisite for routine, preventive, predictive, and corrective maintenance activities to be executed without disruption. The absence of required materials at the point of need



directly elevates the risk of stock-out, prolongs repair durations, and ultimately threatens asset reliability and operational continuity. However, excessive inventory accumulation introduces an opposing set of problems: large amounts of idle capital, high holding costs, and increased exposure to material obsolescence that erodes the company's asset value (Huiskonen, 2001; Kennedy et al., 2002). This tension between material availability and inventory efficiency represents the fundamental challenge in maintenance inventory management within asset-intensive industries.

Based on internal inventory record, the total inventory value at PT Pertamina Patra Niaga - Refinery Operations Directorate (PT PPN) amounted to IDR 3,663,353,646,818 in 2025, encompassing all inventory categories across refinery units. The magnitude of this inventory value highlights a critical managerial concern regarding whether inventory management practices have been implemented effectively and efficiently. From both operational and financial perspectives, such a substantial level of inventory represents significant capital allocation that must be continuously evaluated to ensure it contributes optimally to operational reliability, inventory productivity, and overall value creation.

To assess inventory management performance, this study employs the Inventory Turnover Ratio (TOR) as the primary performance measurement indicator. TOR reflects the extent to which inventory is utilized over a given period and serves as a widely recognized metric for evaluating inventory efficiency. Within PT PPN, TOR is calculated and monitored periodically using the Procurement Integration System Application (PRISMA), specifically through the Inventory Dashboard, enabling both historical analysis and performance tracking over time.

In addition to being measured at both refinery unit and corporate levels, TOR is further analyzed across three major inventory categories: (1) Chemical and Catalyst materials, (2) Routine Maintenance materials, and (3) Turnaround and Overhaul (TA/OH) program materials. The TOR values across these categories exhibit considerable variation, reflecting differences in inventory characteristics, consumption patterns, material criticality, and operational requirements. Such variation indicates that inventory efficiency challenges are not uniformly distributed but are concentrated within specific segments of maintenance inventory.

Based on the corporate TOR target of 0.60, significant improvement opportunities remain in the Routine Maintenance category. Compared to Chemical and Catalyst and TA/OH materials, which consistently achieve TOR levels above the target threshold, Routine Maintenance inventory demonstrates a substantial performance gap. As of December 2025, Routine Maintenance TOR was recorded at approximately 0.42, indicating a gap relative to the corporate target. This condition reflects low inventory productivity and highlights inefficiencies in the utilization of maintenance materials.

A critical indicator of potential inventory management inefficiency at PT PPN is the magnitude of material provisioning for MRO spare parts. As of the 2025 fiscal year, the cumulative balance of provisioning for non-hydro (maintenance) spare part inventory reached USD 50,148,638. When juxtaposed against the total MRO inventory value of approximately USD 3.78 billion, the provisioning exposure stands at above 20%, indicating a substantial proportion of inventory materials that are categorized as slow-moving or non-moving. This scale of provisioning accumulation constitutes a significant signal of potential inefficiency in the management of maintenance spare parts, warranting a systematic and evidence-based investigation.



It is important to note, however, that the provisioning balance figure of USD 50,148,638 represents the cumulative stock of all outstanding provisions across aging brackets, rather than the full provisioning charge recognized in the current period. The provisioning expense actually incurred during the 2025 fiscal year represents the incremental addition to the provision balance, calculated as the difference between the 2025 and 2024 closing balances, amounting to USD 736,249. This distinction is analytically significant: the current-year expense reflects the marginal deterioration in inventory utilization, while the cumulative balance reflects the historical depth of slow-moving material accumulation. Both dimensions are relevant to understanding the structural provisioning exposure embedded within the MRO inventory portfolio.

Critically, the magnitude of provisioning accumulation cannot be interpreted as a straightforward indicator of managerial failure. The refinery industry is characterized by a uniquely complex operational environment, in which the criticality of equipment reliability, the length of material procurement lead times, and the consequences of operational downtime fundamentally shape spare part stocking decisions. In this context, retaining materials with low or zero movement frequency may reflect deliberate and rational risk management choices rather than inventory mismanagement. Policies governing Minimum Stock Level (MSL), Insurance materials, and the Reliability-Centered Spare Part (RCSP) program are specifically designed to guarantee material availability for critical equipment under scenarios of unexpected failure or catastrophic operational risk. These policies inherently tolerate the accumulation of low-turnover inventory in order to preserve asset reliability and continuity of refinery operations. Furthermore, to date there exists no universally established or internally mandated benchmark that defines the ideal provisioning threshold for non-hydro MRO materials, making direct normative comparison inherently limited. Accordingly, research in this domain must move beyond binary assessments of efficiency and instead examine the underlying drivers, contextual justifications, and governance mechanisms that shape provisioning accumulation within the refinery maintenance context.

The elevated provisioning balance of MRO spare parts at PT PPN, when examined in conjunction with the absence of a defined benchmark for acceptable provisioning levels and the complexity inherent to refinery maintenance operations, establishes a multifaceted research problem that spans operational, strategic, and reliability dimensions. The central question is not whether provisioning is too high in absolute terms, but rather whether the current inventory management practices, including stocking strategies, criticality assessments, material lifecycle governance, and reliability policies, are sufficiently aligned with actual maintenance needs and organizational risk tolerance. This condition establishes a compelling basis for research. Although previous studies have extensively examined maintenance spare-part inventory management, most have focused on isolated aspects such as inventory classification techniques (Devnani et al., 2010; Kumar & Shukla, 2022), forecasting approaches (Boylan & Syntetos, 2010), or reliability-centered maintenance strategies (Moubray, 1997; Basten & Van Houtum, 2014). Existing studies rarely integrate inventory value, material criticality, movement behavior, reliability requirements, and financial provisioning exposure within a unified decision-making framework. Furthermore, empirical evidence from asset-intensive refinery environments remains limited, particularly regarding how inventory optimization can simultaneously improve turnover performance and preserve operational reliability. Addressing this gap, the present study integrates ABC–VED–FSN classification with Reliability-Centered Spare Parts (RCSP) principles and financial performance



considerations to develop a comprehensive inventory optimization framework tailored to refinery maintenance operations that rigorously investigates the factors driving slow-moving spare part accumulation and evaluates the adequacy of existing governance mechanisms in balancing material availability against inventory efficiency.

Given these conditions, maintenance inventory management at PT PPN can be characterized as a multi-dimensional issue involving operational inefficiency, reliability constraints, and financial impact. Therefore, this study focuses on optimizing maintenance inventory through a movement-based classification approach integrated with a Reliability-Centered Sparepart (RCSP) framework and financial performance considerations. By using 2025 material movement data as the baseline condition, this research aims to generate data-driven insights and practical managerial recommendations to improve inventory turnover, enhance operational efficiency, maintain asset reliability, and reduce financial exposure from provisioning. Ultimately, the findings are expected to support the company's inventory optimization roadmap for the 2026–2030 period.

METHODOLOGY

3.1 Research Design

This study employed a convergent mixed-methods case study design (Creswell, 2009), in which qualitative and quantitative data were collected and analyzed during the same research period and subsequently integrated during interpretation. The qualitative component was used to identify organizational and governance-related causes of inventory inefficiency, while the quantitative component evaluated inventory characteristics and financial implications through ABC–VED–FSN analysis. The integration of both strands enabled triangulation and the development of a comprehensive inventory optimization framework. to investigate maintenance inventory management practices at PT Pertamina Patra Niaga – Refinery Operations Directorate (PT PPN). A case study strategy was selected because the research problem is embedded within a specific organizational context characterized by complex interactions among maintenance, reliability, procurement, warehousing, and financial functions. This approach enables an in-depth understanding of operational practices, managerial decision-making processes, and inventory governance mechanisms influencing maintenance inventory performance.

The study adopted both exploratory and prescriptive orientations. The exploratory phase aimed to identify the underlying causes of slow-moving and non-moving inventory accumulation, while the prescriptive phase focused on developing an integrated inventory optimization framework capable of improving inventory turnover performance without compromising asset reliability.

3.2 Data Collection

Data were collected through triangulation of multiple sources to enhance the validity and credibility of the findings. Three complementary data collection methods were employed: semi-structured interviews, direct observation, and document analysis.

3.2.1 Semi-Structured Interviews

Semi-structured interviews were conducted with 40 key informants representing five organizational functions directly involved in maintenance inventory management: warehouse management, maintenance planning, reliability engineering, procurement, and finance. Informants were selected using purposive expert sampling based on their experience and involvement in inventory-related decision-making processes.



The interviews explored inventory management practices, material consumption behavior, spare-part criticality assessment, procurement planning, inventory governance mechanisms, and financial implications associated with inventory performance. All interviews were recorded, transcribed, and subsequently analyzed using thematic analysis.

3.2.2 Direct Observation

Field observations were conducted to obtain a contextual understanding of inventory management practices within refinery operations. Observation activities focused on inventory storage conditions, material identification practices, stock handling procedures, warehouse utilization, inventory recording processes, and coordination between warehouse and maintenance personnel. Observational evidence was documented through field notes and used to validate findings derived from interviews and documentary analysis.

3.2.3 Document and Secondary Data Analysis

Quantitative and documentary evidence were obtained from internal organizational records and information systems. The primary datasets included:

- Material movement and inventory records extracted from the PRISMA ERP system;
- Inventory Turnover Ratio (TOR) reports;
- Inventory provisioning records and aging reports;
- Reliability-Centered Spare Parts (RCSP) classifications;
- Minimum Stock Level (MSL) and insurance material records; and
- Corporate policies governing inventory management and provisioning practices.

The dataset covered maintenance inventory transactions and stock movements during fiscal year 2025, which served as the baseline period for analysis.

3.3 Data Analysis

The analysis was conducted through sequential qualitative and quantitative stages.

3.3.1 Qualitative Analysis

Interview transcripts and observation notes were analyzed using thematic analysis. The analytical process involved familiarization with the data, initial coding, theme generation, theme refinement, and interpretation. The objective was to identify recurring patterns and root causes contributing to inventory inefficiency.

The identified themes were subsequently synthesized into root-cause categories representing organizational, procedural, and governance-related factors influencing inventory performance.

3.3.2 Quantitative Inventory Analysis

Inventory performance was evaluated using Inventory Turnover Ratio (TOR) as the primary efficiency indicator. To identify inventory segments requiring differentiated management strategies, a multidimensional inventory classification approach was applied.

The classification framework integrated:

- ABC Analysis, to classify inventory according to annual consumption value;
- VED Analysis (Vital–Essential–Desirable), to assess operational criticality; and
- FSN Analysis (Fast-Moving–Slow-Moving–Non-Moving), to evaluate inventory movement behavior based on material issuance frequency.

The integration of these three classification methods enabled simultaneous assessment of inventory value, criticality, and movement characteristics, thereby supporting more targeted inventory optimization strategies.



3.3.3 Financial Impact Assessment

Financial analysis was conducted to quantify the economic consequences of slow-moving and non-moving inventory. The assessment focused on three dimensions:

1. Inventory value tied to low-movement inventory categories;
2. Inventory provisioning exposure based on aging policies; and
3. Potential working-capital release resulting from inventory optimization initiatives.

Provisioning calculations followed the company's inventory valuation policy, which applies progressive provisioning rates according to inventory aging.

3.3.4 Framework Development

The final stage involved integrating qualitative findings, inventory classification results, and financial analyses into a comprehensive maintenance inventory optimization framework. The framework was designed to balance three strategic objectives: operational efficiency, asset reliability, and financial performance.

The proposed framework incorporates differentiated inventory treatment strategies, governance mechanisms, inventory review processes, and reliability-based inventory management principles to support sustainable improvement in inventory turnover while maintaining spare-part availability for critical refinery assets.

RESULTS AND DISCUSSION

4.1 Maintenance Inventory Performance Assessment

The assessment of maintenance inventory performance across six refinery units revealed persistent inefficiencies in inventory utilization. The average Inventory Turnover Ratio (TOR) recorded in 2025 was 0.67, substantially below the corporate target of 0.95. The declining trend observed throughout the year, from 0.85 in January to 0.42 in December, indicates that inventory accumulation grew faster than actual material consumption. This condition suggests excessive inventory investment relative to operational requirements and reflects limited inventory productivity.

Table 1. Inventory Turnover Performance Baseline 2025 by Refinery Unit

Refinery Unit	TOR
RU II Dumai	0.56
RU III Plaju	0.78
RU IV Cilacap	0.71
RU V Balikpapan	0.84
RU VI Balongan	0.54
RU VII Kasim	0.61
PT PPN Average	0.67
Corporate Target	0.95

The findings further demonstrate that inventory inefficiency extends beyond turnover performance. A substantial proportion of inventory consisted of slow-moving and non-moving materials, resulting in significant working capital being tied up in inactive stock. Simultaneously, several refinery units continued to experience stock-out events for maintenance-critical materials, indicating the coexistence of excess inventory and material shortages. This paradox highlights structural weaknesses in inventory planning and governance.



From a financial perspective, PT PPN recorded a cumulative provisioning balance of USD 50.15 million in 2025. Although the annual increase in provisioning was lower than in previous years, the continuously growing provision balance indicates the persistence of aging inventory and unresolved inventory rationalization challenges. Consequently, inventory inefficiency represents not only an operational concern but also a significant financial burden through reduced asset quality and constrained working capital utilization.

4.2 Root Causes of Inventory Inefficiency

Thematic analysis and root cause analysis identified five interconnected causes of slow-moving and non-moving inventory accumulation.

The first and most significant factor is the absence of criticality-based inventory segmentation. Inventory policies are predominantly governed by uniform minimum stock level practices despite substantial differences in equipment criticality, failure consequences, and procurement lead times. As a result, materials with low operational importance frequently receive the same stocking treatment as reliability-critical spare parts.

The second factor relates to deficiencies in master data quality and material traceability. Inaccurate material records, incomplete maintenance histories, and limited visibility of inventory movement reduce forecasting accuracy and impair decision-making quality. Similar observations have been reported in previous maintenance inventory studies, which identify information quality as a critical determinant of inventory performance.

The third factor is the lack of a standardized periodic inventory review mechanism. Materials often remain in inventory for extended periods without systematic reassessment of operational relevance, consumption probability, or disposal eligibility. Consequently, inactive inventory accumulates over time and gradually transitions into provisioned inventory categories.

The fourth factor concerns disposal constraints arising from governance and regulatory requirements. Fully provisioned materials frequently remain in inventory because disposal procedures require extensive administrative approvals. These procedural barriers reduce the organization's ability to remove obsolete materials from inventory records efficiently.

The fifth factor is conservative procurement planning. Maintenance planners commonly include contingency allowances beyond calculated requirements to mitigate stock-out risks. While intended to improve reliability, such practices contribute to inventory accumulation when not supported by adequate stock verification and criticality assessment mechanisms.

Collectively, these findings indicate that inventory inefficiency is generated by a combination of planning behavior, governance limitations, information quality issues, and organizational risk management practices. Therefore, sustainable inventory improvement requires systemic intervention rather than isolated operational adjustments.


Table IV. 1 Frequency-Impact Matrix Root Cause

RC	Root Cause	Frequency	Functional Area	Priority
RC1	Absence of Criticality-Based Inventory Segmentation Strategy (Homogeneous MSL Policy)	28	Planning, Reliability, Warehousing, Finance	Critical
RC2	Inaccurate Master Data and Material Traceability Records (KIMAP, BOM, Work Order History, SAP)	24	Planning, Reliability, Warehousing, Procurement, Finance	Critical
RC3	Absence of Consistent and Standardized Periodic Inventory Review Across Refineries	20	Reliability, Warehousing, Procurement, Finance	Critical
RC4	Structural Barriers to State-Owned Enterprise (SOE) Disposal Processes and Accumulation of Provisioning Burden	18	Finance, Warehousing, Procurement	High
RC5	Over-Conservative Planning and Changes in TA/OH Scope During Execution	16	Planning, Warehousing, Finance	High

4.3 Multi-Dimensional Inventory Classification

4.3.1 ABC Classification

The ABC analysis of 41,003 maintenance inventory items revealed a highly concentrated value structure. Class A materials represented only 9.6% of total stock keeping units but accounted for approximately 80% of total inventory value, equivalent to IDR 1.25 trillion. In contrast, Class C materials represented more than 74% of inventory items while contributing only 5% of total inventory value.

These results confirm the Pareto principle and indicate that managerial attention should be focused primarily on a relatively small number of high-value inventory items. The concentration of financial exposure within Class A inventory suggests substantial opportunities for inventory optimization through targeted management interventions.

Table IV. 2 ABC Analysis Routine Maintenance PT PPN

ABC Class	Item Count	% of Items	Total Value (IDR)	Total Value (%)	Avg Value / Item (IDR)	Max Value (IDR)	Min Value (IDR)
A	3.941	9,6%	1.254.721.702.061	80,0%	318.376.479	14.046.000.000	76.362.795
B	6.653	16,2%	235.272.756.164	15,0%	35.363.408	76.360.052	15.000.000
C	30.409	74,2%	78.434.186.509	5,0%	2.579.308	15.000.000	1
TOTAL		100,0%	1.568.428.644.734	100,0%			



4.3.2 FSN Classification and Provisioning Exposure

The FSN classification demonstrated a strong relationship between inventory movement behavior and financial exposure. Fast-moving inventory generated no provisioning burden because materials continued to exhibit regular consumption patterns. However, provisioning exposure increased substantially as inventory aging intensified.

Table IV. 3 FSN Classification Inventory Items

Kode FSN	Kategori FSN	Jumlah Item	% Item	Value (IDR Billion)
F	Fast Moving	7.552	18.42%	635.21
S	Slow Moving	8.456	20.62%	593.44
N	Non Moving	24.995	60.96%	339.77

The most significant finding emerged within the non-moving category. Although non-moving materials accounted for approximately IDR 339.77 billion in inventory value, they generated provisioning exposure of IDR 338.22 billion, representing more than 80% of total provisioning exposure. This finding indicates that financial inefficiency is highly concentrated within aging inventory rather than actively utilized materials.

Table IV. 4 Balance Changes in the Provision for Inventory Valuation Allowance for Materials at PT PPN (2023–2025)

Year	Opening Balance (USD)	Increase (USD)	Closing Balance (USD)	YoY Growth (%)
2023	–	46,765,961	46,765,961	–
2024	46,765,961	2,646,428	49,412,389	+5.66%
2025	49,412,390	736,248	50,148,638	+1.49%

Source: PT PPN 2025 Financial Statements

The results suggest that inventory optimization initiatives targeting non-moving materials can simultaneously improve turnover performance, reduce provisioning expenses, and release working capital for more productive organizational use.

4.3.3 Integrated ABC–VED–FSN Analysis

The integration of value, criticality, and movement classifications produced a more comprehensive understanding of inventory behavior. The analysis revealed that ADS and ADN categories collectively represented IDR 673.38 billion, equivalent to 42.9% of total inventory value, while accounting for only 5.84% of total inventory items.

This finding identifies ADS and ADN materials as the primary target for optimization interventions because they combine high financial significance with low utilization rates. Unlike conventional inventory reduction approaches, the integrated classification framework enables managers to distinguish between strategically justified inventory and genuinely inefficient inventory accumulation.

The results support previous studies emphasizing that inventory management decisions should simultaneously consider value contribution, movement characteristics, and operational criticality rather than relying on a single classification dimension.



Table IV. 5 ABC-VED-FSN Classification

Classification	ABC	VED	FSN	Total Items	% Total Items	Total Value (IDR)	% Total Value
ADF	A	D	F	1.229	3,00%	458.009.780.396	29,20%
ADN	A	D	N	911	2,22%	204.845.317.122	13,06%
ADS	A	D	S	1.486	3,62%	468.536.357.141	29,87%
AEF	A	E	F	153	0,37%	58.778.372.433	3,75%
AEN	A	E	N	4	0,01%	747.848.499	0,05%
AES	A	E	S	79	0,19%	26.718.719.749	1,70%
AVF	A	V	F	64	0,16%	31.627.784.579	2,02%
AVS	A	V	S	15	0,04%	5.457.522.142	0,35%
BDF	B	D	F	1.619	3,95%	59.171.285.112	3,77%
BDN	B	D	N	2.740	6,68%	91.797.717.885	5,85%
BDS	B	D	S	1.920	4,68%	70.625.216.929	4,50%
BEF	B	E	F	211	0,51%	8.103.039.576	0,52%
BEN	B	E	N	7	0,02%	239.485.296	0,02%
BES	B	E	S	93	0,23%	3.403.060.180	0,22%
BVF	B	V	F	54	0,13%	1.713.570.246	0,11%
BVN	B	V	N	2	0,00%	57.938.240	0,00%
BVS	B	V	S	7	0,02%	161.442.700	0,01%
CDF	C	D	F	3.806	9,28%	15.714.279.014	1,00%
CDN	C	D	N	21.320	52,00%	42.028.951.924	2,68%
CDS	C	D	S	4.629	11,29%	17.392.092.638	1,11%
CEF	C	E	F	333	0,81%	1.642.904.754	0,10%
CEN	C	E	N	11	0,03%	55.209.326	0,00%
CES	C	E	S	199	0,49%	997.767.001	0,06%
CVF	C	V	F	83	0,20%	452.892.519	0,03%
CVS	C	V	S	28	0,07%	150.089.333	0,01%
TOTAL				41.003	100.00%	1.568.428.644.734	100.00%

4.4 Discussion

The findings contribute to maintenance inventory management literature in three important ways. First, the study demonstrates that inventory turnover alone is insufficient for evaluating maintenance inventory performance. In refinery environments, many low-turnover materials serve critical reliability functions and therefore cannot be assessed solely using efficiency-oriented metrics. This finding supports reliability-centered maintenance theory, which emphasizes the strategic importance of spare-part availability for operational continuity.

Second, the results show that inventory inefficiency is primarily a governance problem rather than a warehousing problem. The accumulation of slow-moving inventory was strongly associated with planning practices, review mechanisms, master data quality, and disposal governance. This observation extends previous inventory management research by highlighting organizational processes as key drivers of inventory performance.



Third, the integration of ABC, VED, and FSN classifications with Reliability-Centered Spare Parts (RCSP) principles provides a practical mechanism for balancing operational efficiency and asset reliability. Existing studies typically emphasize either inventory reduction or reliability assurance. The proposed framework bridges these perspectives by enabling differentiated inventory treatment strategies based on both economic and operational considerations.

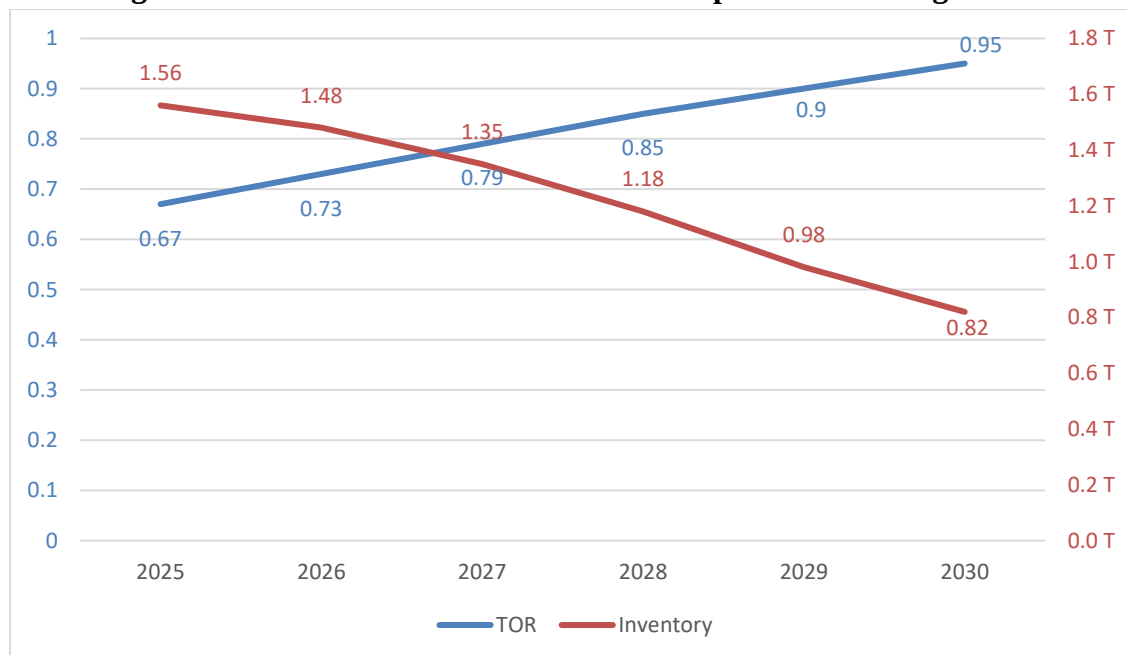
Table IV. 6 Projected Provisioning Reduction

Year	TOR	Inventory (Rp Trillion)	Inventory Reduction vs 2025	Provision (Rp Billion)	Provision Reduction vs 2025 (Rp Billion)
2025	0.67	1.56	-	412.79	-
2026	0.73	1.48	5%	391.62	21.17
2027	0.79	1.35	13%	357.22	55.57
2028	0.85	1.18	24%	312.24	100.55
2029	0.90	0.98	37%	259.32	153.47
2030	0.95	0.82	47%	216.98	195.81

Source: Internal data of PT PPN; compiled by the researcher (2026)

The study therefore proposes an Integrated Maintenance Inventory Optimization Framework that aligns inventory efficiency objectives with reliability requirements and financial performance targets. Under the proposed roadmap, TOR is projected to increase from 0.67 to 0.95 by 2030, while cumulative provisioning exposure is expected to decrease significantly and approximately IDR 740 billion in working capital may be released from unproductive inventory holdings.

Figure IV. 1 TOR Performance and Consumption Value Target



Source: Internal data of PT PPN; compiled by the researcher (2026)

Overall, the results indicate that sustainable inventory optimization in refinery operations requires a balanced approach that combines inventory segmentation, reliability-centered decision making,



governance strengthening, and financial discipline. Such an approach allows organizations to improve inventory productivity without compromising asset reliability or operational continuity.

Table IV.7 Differentiated Inventory Treatment Strategy

Based on ABC-VED-FSN Classification

Treatment Strategy	Matrix Code	Total Items	Total Value (IDR Billion)	Key Management Action	Root Cause Addressed
PROTECT	AVF	64	31.63	Maintain safety stock; validate MSL via RCSP; align reorder point with consumption; prevent uncontrolled reduction	RC1
	BVF	54	1.71		
	BEF	211	8.10		
	CVF	83	0.45		
	CEF	333	1.64		
REVIEW & PROTECT	AVS	15	5.46	Periodic BOM & RCSP validity review; verify active equipment link; recalibrate quantity to minimum defensible level	RC1, RC3
	AES	79	26.72		
	BVS	7	0.16		
	BES	93	3.40		
	CVS	28	0.15		
OPTIMIZE & RATIONALIZE	AVN	-	-	Technical review for active BOM link; explore VMI/consignment alternatives; correct master data; reduce stock to minimum justified level	RC1, RC2, RC3
	BVN	2	0.06		
	CVN	-	-		
	AEN	4	0.75		
	BEN	7	0.24		
	CEN	11	0.06		
	CES	199	1.00		
REDUCE & OPTIMIZE	ADF	1,229	458.01	Priority consumption program; inter-RU redeployment; procurement moratorium for items with existing stock; demand-aligned MSL recalibration	RC1, RC5
	ADS	1,486	468.54		
	ADN	911	204.85		
	AEF	153	58.78		
	BDF	1,619	59.17		
	BDS	1,920	70.63		
	BEF	211	8.10		
DISPOSE & REDUCE	CDF	3,806	15.71	Initiate disposal per TKO B09-006; quarantine in SAP; accelerate write-off approval; eliminate re-procurement of inactive items	RC1, RC4
	CDS	4,629	17.39		
	CDN	21,320	42.03		
	BDN	2,740	91.80		
TOTAL	25 Codes	41,003	1,568.43		

CONCLUSIONS

This conclusion drawn from the research findings, synthesizing the analytical outcomes of the root cause analysis, multi-dimensional inventory classification, and integrated optimization framework developed in the preceding chapters to address the three core research questions of this study, as follows:



1. The accumulation of slow-moving and non-moving maintenance inventory at PT PPN is driven by five interconnected root causes. The absence of a criticality-based inventory segmentation strategy (RC1, frequency: 28) is the primary driver, as uniform Minimum Stock Level practices are applied across materials with fundamentally different operational roles. This is compounded by inaccurate master data and BOM records (RC2, frequency: 24), which enable duplicate procurement; the absence of standardized periodic inventory review across refinery units (RC3, frequency: 20); structural SOE disposal barriers that have left USD 39.5 million in fully provisioned materials undisposed of (RC4, frequency: 18); and over-conservative planning with 15–20% contingency allowances applied without prior stock verification (RC5, frequency: 16). Together, these five causes form a self-reinforcing system that produces the observed maintenance material TOR of 0.67 against a corporate target of 0.95.
2. Maintenance inventory turnover at PT PPN can be improved from TOR 0.67 to the corporate target of 0.95 by 2030 without compromising asset reliability, primarily through systematic reduction of the inventory base rather than demand stimulation. ABC-VED-FSN analysis of 41,003 active SKUs valued at IDR 1,568.43 billion revealed that the ADS and ADN categories (Class A Desirable Slow-Moving and Non-Moving materials) account for IDR 673.38 billion (42.9% of total inventory value) despite comprising only 5.84% of SKUs, making them the highest-priority target for working capital improvement. The five-treatment differentiated strategy (PROTECT, REVIEW & PROTECT, OPTIMIZE & RATIONALIZE, REDUCE & OPTIMIZE, DISPOSE & REDUCE) ensures that rationalization is calibrated to each material's criticality, preserving operational reliability throughout. Achieving TOR 0.95 requires a 47% reduction in inventory value, from IDR 1.56 trillion to IDR 0.82 trillion, with material performance disparities across refinery units (RU II at TOR 0.40; RU V at TOR 0.92) confirming the need for unit-specific interventions alongside consolidated improvement programs.
3. Integrated Maintenance Inventory Optimization Framework developed in this study provides a comprehensive, evidence-based roadmap for addressing the structural drivers of inventory inefficiency at PT PPN. Grounded in Wild's (2002) four inventory management principles and calibrated to PT PPN's 2025 baseline, the framework translates ABC-VED-FSN classification outputs into five business solutions directly mapped to RC1–RC5, sequenced across a three-phase implementation roadmap from 2026 to 2030. Full execution is projected to reduce cumulative provisioning exposure by IDR 247.19 billion, from IDR 411.99 billion to IDR 164.80 billion, and release approximately IDR 740 billion in working capital, establishing a governance architecture capable of sustaining inventory performance beyond the planning horizon.


Table IV. 8 Summarize Phased Structure of Implementation Roadmap

Phase	Period	TOR Target	Inventory Value (IDR Trillion)	Reduction vs 2025	Objectives
Baseline	2025	0.67	1.56	–	Baseline assessment, ABC-VED-FSN classification
Phase 1	2026–2027	0.73–0.79	1.35–1.48	5–13%	Governance foundation; PROTECT & REVIEW-PROTECT; Priority Consumption Program; master data remediation
Phase 2	2028	0.85	1.18	24%	OPTIMIZE & RATIONALIZE full rollout; cross-RU redeployment; DISPOSE & REDUCE pilot
Phase 3	2029–2030	0.90–0.95	0.82–0.98	37–47%	Full-scale disposal; digital integration; governance institutionalization; TOR 0.95 achievement

Source: Internal data of PT PPN; compiled by the researcher (2026)

Recommendation

Based on the findings of this study, several recommendations are proposed for PT PPN and future researchers. These recommendations are intended to support the implementation of the proposed inventory optimization framework and contribute to the advancement of inventory management practices and research in maintenance-intensive industries.

For PT PPN, it is recommended to prioritize the implementation of the proposed business solutions, particularly the Priority Consumption Program, RCSP expansion, Vendor-Managed Inventory (VMI), and provisioning governance initiatives. Furthermore, inventory governance should be strengthened through regular monitoring of Inventory Turnover Ratio (TOR), slow-moving inventory levels, and provisioning exposure to ensure sustainable inventory optimization while maintaining asset reliability and operational continuity.

For future researchers, it is recommended to evaluate the effectiveness of the proposed inventory optimization framework after implementation using quantitative performance measurements. Further studies may also expand the scope to other asset-intensive industries and explore the application of advanced analytical methods or digital technologies to enhance inventory management performance and support more effective decision-making processes.

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