

Preventive Maintenance Practices for Vessel Machinery at Nasipit Port, Agusan Del Norte

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ABSTRACT

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Preventive maintenance is central to vessel machinery reliability, yet no published study has examined how engineering crew experience relates to specific maintenance practices at Nasipit Port, an international base port in Agusan del Norte, Philippines. This study assessed the current state of preventive maintenance practices for vessel machinery at Nasipit Port and determined whether crew experience level relates to how consistently these practices are performed. The study employed a quantitative descriptive design. Respondents were 24 engineering crew members from eight vessels docked at Nasipit Port (six passenger and two cargo vessels), comprising eight chief engineers, eight fourth engineers, and eight engine ratings, surveyed using a validated, adapted questionnaire and analyzed using frequency and percentage distributions, weighted means, and t-tests. Chief engineers were the most experienced rank (62.5% with 11 or more years), while all engine ratings reported five years or fewer of experience. Regular inspections and cleaning and maintenance received the highest ratings (weighted mean = 3.7 each, "always"), followed by replacement of worn parts and calibration and adjustment (3.5 each), with lubrication practices rated lowest (3.4, "frequently"); the grand mean of 3.6 indicated practices are performed "always." Only regular inspections showed a significant difference by years of experience ($t = -2.10$, $p = 0.041$); the remaining four domains showed no significant difference,

indicating standardized application regardless of seniority. These findings suggest that inspection quality, specifically, depends on accumulated, experience-based judgment, pointing to structured inspection-specific training as a targeted opportunity for less experienced crew at Nasipit Port.

INTRODUCTION

Preventive maintenance is a proactive strategy for maintaining equipment and machinery that focuses on preventing failures before they occur through regular inspection, servicing, and condition-based monitoring, extending equipment lifespan while minimizing unplanned downtime, repair costs, and safety risk (Nasiri & Hamid, 2024). As the maritime industry increasingly relies on advanced and sophisticated machinery, effective preventive maintenance requires a comprehensive understanding of both the specific operating environment and the latest advances in maintenance technology (Xu & Teng, 2024). Kimera and Nangolo (2020) emphasized that a comprehensive preventive maintenance program tailored to each vessel's operating environment, encompassing a detailed inspection schedule, maintenance task list, and spare-parts inventory management, allows seaport operators to significantly reduce unexpected failures and operational disruption; the authors further stressed that skilled, well-trained maintenance personnel and systematic data collection on maintenance outcomes are equally essential to sustaining program effectiveness over time, a conclusion consistent with the broader maintenance management literature identifying organizational commitment and workforce competence, not technology alone, as decisive success factors (Garg & Deshmukh, 2006).

Globally, research on vessel machinery maintenance has increasingly emphasized both technological and human dimensions of preventive maintenance effectiveness. Jimenez, Bouhmala, and Gausdal (2020) proposed a predictive maintenance framework integrating sensor data, machine learning algorithms, and expert knowledge to anticipate vessel machinery failures before they escalate, arguing that such data-driven approaches can be effectively layered onto conventional preventive maintenance practices to improve cost savings and operational reliability. Karatuğ, Arslanoğlu, and Guedes Soares (2022) extended this technological focus to autonomous vessels, proposing a multi-criteria decision-making approach for selecting maintenance strategies that account for cost, reliability, safety, and environmental impact across diverse operating conditions. At the same time, Oosterhout and Bil (2017) cautioned that technological and procedural solutions alone are insufficient: modifying maintenance practices within maritime operations requires a cultural shift, since seafarers' long-standing, practice-based traditions often prioritize immediate problem-solving over proactive maintenance, and successfully embedding preventive maintenance requires collaboration among ship management, port authorities, and seafarers themselves, supported by targeted training and clear communication about its benefits.

Within the Association of Southeast Asian Nations (ASEAN) region, preventive maintenance research has highlighted comparable operational and workforce challenges. Mursidi and Sarjito (2025) analyzed the implementation of ship engine maintenance management systems in Indonesia and found that top management support, sound technical skills, and appropriate technology jointly determine maintenance system effectiveness, and that planned training with systematic evaluation of training outcomes measurably improves technician performance, reducing both downtime and operational cost, a finding directly relevant to the training-investment question this study investigates.

Locally, the Port of Nasipit serves as Agusan del Norte's major seaport, designated by the Philippine Ports Authority as an international base port, and handles a diverse range of vessel types whose varying maintenance requirements, combined with the port's coastal exposure to corrosive marine conditions, complicate the implementation of a standardized preventive maintenance program (Kimera & Nangolo, 2020).

Despite this substantial global and regional literature on preventive maintenance strategy and technology, no published study has evaluated how years of work experience among different engineering ranks, chief engineers, fourth engineers, and engine ratings, relate to the specific preventive maintenance practices performed on vessel machinery at Nasipit Port. This gap justifies the present study, which the researchers undertook to assess the current state of preventive maintenance practices at Nasipit Port and to determine whether engineering crew experience level relates to how consistently these practices are performed, in order to identify specific, evidence-based opportunities for training investment.

FRAMEWORK

This study is anchored on Aristotle's theory of causality, which identifies four distinct causes, material, formal, efficient, and final, as a framework for understanding and optimizing preventive maintenance practices on vessel machinery (Falcon, 2019). The material cause, representing machinery's physical components, is addressed through regular inspection and replacement of parts prone to wear, minimizing the risk of unexpected breakdown. The formal cause, encompassing machinery design and specifications, is addressed by adhering to manufacturer guidelines for maintenance schedules and procedures, ensuring maintenance practices align with each component's intended functionality and longevity.

The efficient cause, representing the actions taken to maintain machinery, is addressed through skilled personnel performing routine inspection, lubrication, and cleaning using appropriate tools and techniques, sustaining peak machinery performance and extended service life; this study's central variable, years of work experience, maps directly onto this efficient cause, since it is the crew's skilled action, not the machinery's design or materials, that this study investigates as a potential source of variation in maintenance quality. The final cause, representing machinery's

underlying purpose, is addressed by aligning maintenance practices with the vessel's and seaport's overall operational goals, since reliable machinery directly supports efficient cargo handling, safe navigation, and port productivity. Addressing all four causes together provides a comprehensive framework through which port operators can proactively mitigate issues, minimize downtime, and optimize operational efficiency, fostering a culture of proactive rather than reactive maintenance across the maritime industry.

OBJECTIVES

This study assessed the preventive maintenance practices for vessel machinery at Nasipit Port through the following specific objectives: (1) determined the demographic profile of the respondents in terms of years of work experience; (2) described the level of preventive maintenance practices for vessel machinery at Nasipit Port as perceived by chief engineers, fourth engineers, and engine ratings in terms of regular inspections, lubrication practices, replacement of worn parts, calibration and adjustment, and cleaning and maintenance; and (3) determined whether a significant difference exists between respondents' years of work experience and preventive maintenance practices at Nasipit Port.

METHODOLOGY

Research Design

The study used a quantitative descriptive design, gathering numerical data to statistically analyze patterns and relationships within the population sample through survey administration (Siedlecki, 2020). This design was used to assess preventive maintenance practices on vessel machinery at Nasipit Port.

Research Site

The study was conducted at Nasipit Port, Barangay Talisay, Nasipit, Agusan del Norte, approximately 2.3 kilometers from the Nasipit terminal proper. The Philippine Ports Authority designated the Port Management Office of Nasipit as an international base port serving the province's northern region.

Participants

Respondents were 24 engineering crew members drawn from eight vessels docked at Nasipit Port (six passenger vessels and two cargo vessels), comprising eight chief engineers, eight fourth engineers, and eight engine ratings.

Data were gathered using a two-part survey questionnaire. Part I captured respondent demographic profile in terms of years of work experience, using a checklist format. Part II, comprising 25 items, measured preventive maintenance practices across five domains, adapted from a validated instrument developed by Song, Tan, and Han (2022) for research on preventive maintenance strategies and

systems for in-service ship equipment, using a four-point Likert scale (4 = always, 3 = frequently, 2 = seldom, 1 = not done).

Research Ethics Protocol

Participation was voluntary, and the researchers minimized risk of harm through prior risk assessment and adaptive data-collection procedures. Informed consent was obtained using a bilingual (English and Cebuano) consent form confirming that respondents understood the study's purpose, were not coerced, retained their right to withdraw at any time, and were assured of confidentiality. All collected data were treated as confidential, stored on a password-protected flash drive accessible only to the research team, and used solely for the stated research purpose.

Data Collection

The data gathering process followed a systematic and ethical procedure. Formal permission was first secured through a letter of intent, signed by the research adviser, and submitted to Nasipit Port management to authorize the conduct of the study and the survey schedule. Subsequently, eight vessels docked at Nasipit Port were selected, and the chief engineer, fourth engineer, and engine ratings aboard each were identified as the target respondents. Informed consent and signed confidentiality agreements were obtained from all participants after confirming their understanding of the study's purpose, procedures, and voluntary nature. The survey questionnaires were then manually distributed to the respondents, with open communication maintained during administration to provide guidance as needed. Upon completion, the instruments were retrieved, verified for completeness, tabulated, and evaluated by the researchers to serve as the basis for the study's findings, conclusions, and recommendations.

Data Analysis

The researchers used frequency and percentage distributions to summarize respondent demographic data, weighted mean to interpret the perceived level of preventive maintenance practices, and a t-test to determine whether a significant difference existed between years of work experience and preventive maintenance practices.

RESULTS AND DISCUSSION

Demographic Profile

Table 1

Respondent profile by rank and years of work experience

Rank	5 years and below	6–10 years	11 years and above
Chief engineer	0 (0%)	3 (37.5%)	5 (62.5%)
Fourth engineer	4 (50%)	3 (37.5%)	1 (12.5%)
Engine ratings	8 (100%)	0 (0%)	0 (0%)

Chief engineers were the most experienced rank, with 62.5% reporting 11 or more years of experience and none reporting fewer than 6 years, consistent with the seniority-based promotion structure of shipboard engineering departments. Fourth engineers showed a more even distribution, with half reporting 5 years or fewer of experience, suggesting this rank functions as a developmental stage in which engineers gain supervised, hands-on experience. All engine ratings reported 5 years or fewer of experience, reflecting their entry-level position within the engine department hierarchy. This experience gradient across ranks is consistent with research showing that maintenance management benefits substantially from skilled operators with comprehensive machinery knowledge, and that organizations with more experienced maintenance workforces demonstrate improved reliability outcomes and more effective early identification of potential failures (Ahuja & Khamba, 2008; Garg & Deshmukh, 2006).

Extent of Preventive Maintenance Practices

Table 2

Extent of preventive maintenance practices by domain

Practice domain	Weighted mean	Verbal description	Rank
Regular inspections	3.7	Always	1.5
Cleaning and maintenance	3.7	Always	1.5
Replacement of worn parts	3.5	Always	3.5
Calibration and adjustment	3.5	Always	3.5
Lubrication practices	3.4	Frequently	5
Grand mean	3.6	Always	

Regular inspections and cleaning and maintenance received the highest ratings (mean = 3.7 each, "always"). Within regular inspections, the highest-rated items concerned inspections being conducted by qualified, trained personnel and inspection tools being properly calibrated (both mean = 3.8 across ranks), while adherence to scheduled maintenance plans and inspection-report documentation scored slightly lower (mean = 3.6 each), suggesting technical execution outpaces administrative rigor. Within cleaning and maintenance, the highest-rated item concerned conducting cleaning safely and in an environmentally responsible manner (mean = 3.9), consistent with compliance expectations under international maritime pollution-prevention standards. Replacement of worn parts and calibration and adjustment followed closely (mean = 3.5 each, "always"), with the highest-rated item in each domain concerning adherence to proper installation and calibration procedures by qualified personnel, while environmentally responsible disposal of worn parts scored comparatively lower, indicating a specific, actionable area for reinforcement.

Lubrication practices received the lowest overall rating (mean = 3.4, "frequently" rather than "always"), with the lowest-rated items concerning adherence to manufacturer-recommended lubrication schedules and regular

lubricant-sample analysis (both mean = 3.3), while lubrication-system inspection scored highest within this domain (mean = 3.5). This pattern is consistent with tribology-based research showing that proper lubricant selection and application are critical to minimizing wear and extending machinery lifespan, and it suggests that while basic lubrication upkeep is well established at Nasipit Port, more systematic oil-analysis practices, a recognized predictive-maintenance technique, remain comparatively underutilized (Owunna & Ikpe, 2023; Xu & Teng, 2024).

Significant Difference Between Experience and Preventive Maintenance Practices

Table 3

Significant difference between years of work experience and preventive maintenance practices

Practice domain	<i>t</i>	<i>p</i> -value	Decision
Regular inspections	-2.10	0.041	Reject the null hypothesis
Cleaning and maintenance	-1.82	0.081	Fail to reject the null hypothesis
Replacement of worn parts	-1.30	0.208	Fail to reject the null hypothesis
Lubrication practices	-1.20	0.244	Fail to reject the null hypothesis
Calibration and adjustment	-1.20	0.243	Fail to reject the null hypothesis

Regular inspections showed a statistically significant difference by years of work experience ($p = 0.041$), the only domain to do so; the remaining four domains, cleaning and maintenance, replacement of worn parts, lubrication practices, and calibration and adjustment, showed no significant difference (all $p > 0.05$), indicating that these four practices are applied in a standardized manner regardless of crew experience level. This pattern suggests that regular inspection quality, specifically, depends on the inspector's accumulated judgment and familiarity with the equipment in ways that more procedurally scripted tasks, such as cleaning routines or scheduled part replacement, do not, since the latter can be more fully specified by written procedure while inspection quality depends more heavily on tacit, experience-based judgment about what constitutes a genuine anomaly. Ahuja and Khamba (2008) similarly found that experienced personnel are better positioned to identify potential equipment failures and optimize maintenance scheduling, directly supporting the interpretation that Nasipit Port's less experienced engine ratings and fourth engineers may benefit from structured inspection-specific training to close this experience-linked gap.

CONCLUSIONS

Preventive maintenance practices for vessel machinery at Nasipit Port are performed at a generally high level across all five domains assessed, with regular inspections and cleaning and maintenance rated highest and lubrication practices rated lowest, though still within the "frequently to always" range. This study's principal contribution beyond existing literature is its demonstration that years of engineering work experience relates to preventive maintenance consistency in a

highly specific rather than uniform way: only regular inspections showed a statistically significant experience-based difference, while cleaning and maintenance, replacement of worn parts, calibration and adjustment, and lubrication practices are performed consistently regardless of crew seniority. This finding refines Aristotle's four-cause framework as applied to maintenance practice by showing that the efficient cause's influence is concentrated in judgment-dependent tasks rather than distributed uniformly across all maintenance activities, suggesting that procedural standardization can substitute for experience in more scripted tasks but not in tasks requiring tacit, accumulated judgment. These findings indicate that structured, inspection-specific training for less experienced fourth engineers and engine ratings, together with continued reinforcement of environmentally responsible parts-disposal and systematic lubricant-sample analysis, represent the most evidence-based opportunities for training investment at Nasipit Port.

TRANSLATIONAL RESEARCH

These findings could be translated into a targeted training investment plan for Nasipit Port's engineering crew. Because regular inspections appear to be the only domain sensitive to years of experience, it is suggested that port management and vessel operators consider prioritizing structured, inspection-specific mentorship and simulation-based training for fourth engineers and engine ratings, pairing less experienced crew with chief engineers during routine inspection rounds to help transfer the tacit, judgment-based skills this study identifies as experience-dependent.

Since lubrication practices scored lowest overall, particularly adherence to manufacturer-recommended lubrication schedules and lubricant-sample analysis, the port and vessel operators may benefit from introducing a basic oil-analysis protocol and a lubrication-schedule compliance checklist accessible to all engineering ranks regardless of seniority. It is recommended that these findings be translated into a simple, plain-language training bulletin and checklist, in English and Cebuano, that Nasipit Port's engineering crew and port management could use directly without needing to interpret the full statistical findings.

This would support the practical uptake of training investment recommended by this study among shipping companies and seaport operators more broadly, consistent with the training-effectiveness evidence documented in comparable ASEAN maritime maintenance research (Mursidi & Sarjito, 2025).

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