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# ANALYSIS OF PROPULSION SYSTEM MODERNIZATION STRATEGY VIA THE KRI X REPOWERING PROGRAM TO ENHANCE WARSHIP OPERATIONAL READINESS

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**Abstract.** The operational readiness of warships is closely linked to the reliability and performance of their propulsion systems, whereas aging naval platforms commonly experience degradation that reduces operational effectiveness and increases maintenance requirements. This study aims to formulate a propulsion system modernization strategy through a repowering program for KRI X. A descriptive qualitative design was applied using primary data from in-depth interviews with seven purposively selected informants and observations, supported by secondary data from document analysis. Interview data were coded and analyzed using NVivo 12 Plus, while internal and external factors were evaluated through SWOT analysis. The results show significant degradation in the main engine, gas turbine, gearbox, and controllable pitch propeller (CPP), which adversely affects speed, endurance, maneuverability, propulsion reliability, and operational readiness. The SWOT analysis positions the program in the Weaknesses–Opportunities (WO) quadrant, indicating a Turn-Around Strategy that uses modernization opportunities to overcome internal weaknesses. Repowering is therefore an appropriate strategic and cost-effective approach to improve propulsion reliability and long-term operational readiness, provided that it is supported by logistics, maintenance, personnel competence, and organizational policy.

**Keywords:** repowering, propulsion system modernization, operational readiness, naval vessel, SWOT analysis, NVivo

## I. INTRODUCTION

A nation's naval power is determined not only by the number of warships it possesses but also by the operational readiness of those assets to execute various operational tasks. In the modern concept of sea power, operational readiness is a critical factor determining a navy's ability to respond to threats, project power, and maintain maritime security on a sustained basis (1). The highly dynamic nature of the maritime strategic environment, the increase in international maritime traffic, and evolving maritime security threats necessitate a high level of readiness for warships to ensure they can perform their duties effectively and continuously.

The operational readiness of warships is influenced by various factors, one of which is the reliability of the ship's platform systems. Among the various platform subsystems, the propulsion system plays a crucial role by generating the thrust necessary for the ship to move, maneuver, and maintain operational capability during missions. According to Molland (2), propulsion system performance results from the integration of the main engine, power transmission system, and propulsor. Malfunctions in any of these components can reduce energy efficiency, increase fuel consumption, and compromise the ship's operational reliability. Baldi et al. (3) emphasize that optimizing propulsion and energy systems contributes significantly to improved operational efficiency and reduced lifecycle costs.

A challenge currently facing many navies worldwide is the phenomenon of an aging fleet. As ships age, their structures, mechanical systems, and support systems undergo degradation, thereby affecting performance and operational readiness. Stopford (4) explains that an increase in a ship's operational age leads to a higher frequency of breakdowns, greater maintenance requirements, and increased operating costs. This situation is further highlighted by a UNCTAD report (5), which identifies fleet modernization as a key challenge for the global maritime sector in maintaining operational efficiency and sustainability.

In the context of warships, propulsion system degradation carries more significant consequences than for commercial vessels, as it directly impacts the ship's ability to execute operational missions. Reduced main engine performance, increased fuel consumption, power transmission system issues, and limited spare parts support can all lower the unit's readiness level. Wróbel, Montewka, and Kujala (6) state that there is a strong link between technical system reliability and operational effectiveness; a decline in system reliability directly affects the ship's ability to perform missions optimally.

KRI X is a warship that has operated beyond its design lifespan and is experiencing a decline in propulsion system

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performance. This condition is characterized by increased maintenance requirements, reduced operational efficiency, and a higher risk of technical malfunctions during operations. Without appropriate modernization measures, this situation could compromise the vessel's operational readiness and diminish its effectiveness in supporting maritime operations.

One modernization alternative widely applied to vessels entering the "aging fleet" phase is the repowering program. Repowering involves replacing or upgrading propulsion systems with more modern, efficient, and reliable technology, thereby avoiding the need for new vessel construction. This approach is considered more economical than building a new platform, as it extends the vessel's operational lifespan while simultaneously enhancing propulsion system performance. Research by Yuarizky et al. (7) demonstrates that repowering can improve engine performance and fuel efficiency. Furthermore, Prayitno et al. (8) state that modernizing technical systems and employing appropriate maintenance strategies contribute to enhanced naval vessel operational readiness.

From the perspective of naval force development, repowering is viewed not merely as a technical solution but as an integral part of the strategy to modernize defense equipment. Feng et al. (9) explain that the success of naval vessel modernization is heavily influenced by the integration of technology, human resources, organizational policy, and logistics support. Consequently, implementing repowering requires planning that considers not only technical aspects but also the various internal and external factors that impact the program's success.

Advancements in modern propulsion technology offer significant opportunities to enhance the efficiency and operational readiness of naval vessels. Mou, Ligteringen, and Xu (10) demonstrate that modern propulsion technologies can improve energy efficiency and reduce fuel consumption. Meanwhile, Kim, Lee, and Shin (11) explain that applying predictive maintenance to propulsion systems can enhance system reliability and reduce operational downtime. These findings are reinforced by Kim and Shin (17), who state that integrating condition monitoring and predictive maintenance enables a significant increase in propulsion system availability. Additionally, Liu, Chen, and Zhou (12) show that optimizing integrated propulsion systems can improve overall vessel operational efficiency. Liu, Chen, and Wang (16) further emphasize that a reliability-centered maintenance approach for propulsion systems contributes to improved operational readiness and the effectiveness of logistics support.

Beyond operational aspects, the modernization of propulsion systems is also linked to the need for improved energy efficiency and sustainability within the maritime sector. Through its Fourth IMO Greenhouse Gas Study, the International Maritime Organization (IMO) has emphasized the importance of enhancing the efficiency of ship propulsion and energy systems as part of the global shipping sector's emission reduction strategy (18). Although warships are not strictly bound by commercial regulations, the development of more efficient technologies remains a crucial consideration in the modernization of military platforms.

Previous studies have addressed propulsion system efficiency, ship modernization, and maintenance strategies, but generally as separate topics. Research specifically examining propulsion system modernization strategies particularly through repowering programs for warships while accounting for both internal and external organizational factors remains relatively limited. Most prior studies have focused on technical aspects such as engine performance, energy efficiency, or maintenance approaches without directly linking them to strategies for enhancing warship operational readiness.

Given this context, an approach is required that can identify the strengths, weaknesses, opportunities, and threats affecting the implementation of repowering programs. SWOT analysis is one method that can be used to systematically evaluate an organization's internal and external conditions and generate strategic alternatives to support decision-making. According to Rangkuti (13), SWOT analysis enables organizations to develop strategies that align with their internal conditions and the dynamics of the external environment they face.

This study employs a qualitative research approach to gain an in-depth understanding of the factors influencing the implementation of the repowering program for KRI X. Creswell and Creswell (14) explain that a qualitative approach is highly suitable for exploring complex and contextual phenomena. Furthermore, Patton (15) states that in-depth interviews enable researchers to obtain a more comprehensive understanding of stakeholders' perceptions, experiences, and considerations.

This research aims to analyze the propulsion system modernization strategy via the repowering program for KRI X to enhance the warship's operational readiness. The analysis involves identifying the internal and external factors affecting the repowering process and formulating strategies to support the successful modernization of the propulsion system in an effective and sustainable manner.

The novelty of this research lies in the integration of NVivo-based qualitative analysis and SWOT analysis to evaluate the warship repowering program through an integrated perspective encompassing technical, operational, logistical, and managerial aspects. Unlike previous studies that generally focused separately on the technical performance of propulsion systems or maintenance strategies, this research develops an analytical framework linking the technical condition of the propulsion system to the warship's operational readiness, thereby generating more comprehensive recommendations for modernization strategies.

## II. RESEARCH METHOD

This study employs a descriptive qualitative approach to analyze the propulsion system modernization strategy specifically through a repowering program for KRI X, with the aim of enhancing the warship's operational readiness. A qualitative approach was selected for its ability to provide a deep understanding of the propulsion system's actual condition, the factors influencing the repowering program's implementation, and the implications for the vessel's operational readiness. According to Creswell and Creswell (14), qualitative research is used to explore and understand complex phenomena by interpreting the experiences, perceptions, and views of informants directly involved in the issue at hand. This approach is deemed appropriate because the modernization of propulsion systems involves not only technical aspects but also interacting operational, logistical, human resource, and organizational policy factors. The study involves seven key informants selected purposively based on their experience and direct involvement in the operation, maintenance, and modernization of the KRI.

The subject of this study is KRI X, a vessel that has operated beyond its design lifespan and is experiencing a decline in propulsion system performance. The research focuses on identifying factors that influence the execution of the repowering program and formulating a propulsion system modernization strategy that supports improved warship operational readiness. The study examines the technical condition of the propulsion system, vessel reliability, logistics and maintenance support, human resource competence, organizational policy support, and propulsion technology developments relevant to warship modernization needs.

The data used in this study comprise both primary and secondary data. Primary data were obtained through in-depth interviews with informants selected via purposive sampling. This technique was employed because it enables the researcher to gather more profound information from individuals possessing competence and experience regarding warship operation, maintenance, and modernization. The research informants include warship operations officers, engineering or machinery officers, logistics support personnel, and personnel involved in warship maintenance and modernization activities. The criteria for informants include a minimum of ten years of work experience, direct involvement in the operation or maintenance of Indonesian Navy warships (KRI), an understanding of ship propulsion systems, and familiarity with the Indonesian Navy's defense equipment modernization policies.

Secondary data were obtained through a review of documentation, including vessel technical specifications, maintenance and operational readiness reports, defense equipment modernization policy documents, reference books, scientific journals, and prior research concerning propulsion systems, repowering, vessel operational readiness, and fleet modernization strategies. These secondary data served to strengthen the theoretical framework and support the interpretation of the research findings.

Data collection involved in-depth interviews, observation, and document review. Semi-structured interviews were conducted using a pre-designed guide, allowing for the collection of consistent information while providing informants the opportunity to elaborate on their experiences and perspectives. According to Patton (15), in-depth interviewing is an effective technique for eliciting information regarding informants' experiences, perceptions, and considerations concerning a specific phenomenon. In addition to interviews, observations were conducted to gain a realistic understanding of the propulsion system's condition and the vessel's operational readiness; observations also served to verify information obtained during interviews. Meanwhile, the document review involved examining various records related to the vessel's technical condition, maintenance programs, and applicable modernization policies.

Data analysis was carried out in stages using NVivo 12 Plus software and SWOT analysis. All interview data were first transcribed and processed using NVivo 12 Plus. The analysis proceeded through open coding, axial coding, and thematic categorization to identify patterns, relationships, and factors influencing the implementation of the repowering program. The use of NVivo aimed to systematize the qualitative data analysis and facilitate the identification of key themes emerging from the interviews. Furthermore, NVivo was used to generate data visualizations such as word frequency lists, hierarchy charts, and project maps to assist in interpreting the research findings.

Factors derived from the NVivo analysis were classified into internal and external categories and subsequently analyzed using the SWOT (Strengths, Weaknesses, Opportunities, Threats) method. According to Rangkuti (13), SWOT analysis is a method used to identify the strengths, weaknesses, opportunities, and threats affecting an organization or program, thereby serving as a basis for strategy formulation. In this study, the SWOT analysis was conducted through several stages: identifying internal and external factors; compiling the Internal Factor Analysis Summary (IFAS) and External Factor Analysis Summary (EFAS) matrices; assigning weights and ratings to each factor; calculating total scores for internal and external factors; determining the strategic position on the SWOT diagram; and formulating strategic alternatives based on combinations of Strengths–Opportunities (SO), Weaknesses–Opportunities (WO), Strengths–Threats (ST), and Weaknesses–Threats (WT) factors.

The weighting and rating of each SWOT factor were performed by seven expert informants who were also the interview informants comprising personnel from operations, logistics, and technical divisions directly involved in the operation and maintenance of KRI X. Assessments were conducted using a 1–4 scale, where higher values indicated a greater degree of influence and importance regarding the success of the repowering program. The resulting weights were then used to construct the IFAS and EFAS matrices, which served as the basis for determining the strategic position within the SWOT matrix. Expert informants were selected purposively based on their experience, positions, and direct involvement in decision-making regarding the operation, maintenance, and modernization of the warship.

Subsequently, the SWOT analysis results were used to formulate a propulsion system modernization strategy via a repowering program best suited to the condition of KRI X. The resulting strategy is expected to effectively and sustainably support the enhancement of the warship's operational readiness, taking into account internal organizational conditions and external environmental dynamics. To ensure the credibility and validity of the research findings, verification was conducted using source and method triangulation techniques. Source triangulation involved comparing information obtained from informant groups with diverse backgrounds, while method triangulation entailed comparing results from interviews, observations, and document studies. Furthermore, the identified SWOT factors and the formulated strategy were

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validated through expert judgment, involving specialists in warship operations, marine engineering, and maintenance. This step was taken to ensure the findings aligned with empirical realities and could serve as a basis for decision-making regarding the modernization of the warship's propulsion system.

Overall, the research process encompassed the identification of propulsion system issues on KRI X; data collection via interviews, observations, and document studies; data analysis using NVivo 12 Plus; identification of internal and external factors; construction of IFAS and EFAS matrices; SWOT analysis; formulation of a propulsion system modernization strategy through a repowering program; and the development of recommendations to improve the warship's operational readiness.

## III. RESULTS AND DISCUSSION

### Existing Condition of the KRI X Propulsion System

KRI X is a warship that has been in service for over four decades and currently faces challenges typical of an aging fleet. As the vessel ages, various propulsion system components have suffered performance degradation due to material wear, structural fatigue, limited spare parts support, and increased maintenance requirements. These conditions affect not only the ship's technical aspects but also its operational readiness to support maritime missions.

Pre-Overhaul Test and Inspection (POT&I) results reveal various technical issues with KRI X's propulsion system, indicating a decline in overall system reliability. Regarding the main engines, findings include significantly elevated operating temperatures in several cylinders, exhaust gas temperature imbalances, and signs of reduced combustion efficiency. These conditions indicate engine performance degradation, which increases the risk of component failure during operations. Furthermore, rising cooling system temperatures point to reduced heat dissipation effectiveness, creating a potential risk of overheating if the ship operates under high loads for extended periods.

Regarding the gas turbine system, the unit was found to be incapable of optimal operation due to a governor malfunction, preventing the ship from utilizing the full power of its CODOG (Combined Diesel or Gas) configuration. The gas turbine's inoperability forces the ship to rely solely on the main engines for propulsion, resulting in reduced acceleration capabilities and a lower maximum speed. This situation directly impacts operational flexibility, particularly during missions requiring rapid response and high-speed maneuvering.

Similar issues were also identified in the gearbox and controllable pitch propeller (CPP) systems. Inspection results revealed oil leaks, gear pump damage, low hydraulic oil pressure, and excessive vibration in several power transmission components. The drop in CPP system pressure compromised the propeller blade pitch adjustment mechanism, thereby reducing the efficiency of power transfer from the engine to the propeller. Consequently, a portion of the power generated by the engine could not be effectively converted into vessel thrust.

Overall, the inspection findings indicate that the issues were not isolated to individual components but had impacted the integrated performance of the propulsion system. The decline in main engine performance, the inoperability of the gas turbine, and malfunctions in the gearbox and CPP significantly impaired the propulsion system's thrust-generating capability. These conditions resulted in reduced operational speed, diminished cruising endurance, increased maintenance resource consumption, and lowered operational readiness for maritime missions.

These findings align with Stopford (4), who noted that vessels entering the "aging fleet" phase typically experience higher equipment failure rates, rising maintenance costs, and reduced operational efficiency. Furthermore, Wróbel et al. (6) explain that technical system reliability is a key factor determining a vessel's operational readiness. Thus, the condition of KRI X's propulsion system highlights the need for comprehensive modernization measures to sustain the vessel's operational capabilities in the long term.

From the perspective of naval force development, this situation demonstrates that modernizing the propulsion system through a repowering program is no longer merely a technical option but an operational necessity. A repowering program is expected to overcome the limitations of the existing propulsion system, enhance reliability and operational efficiency, and extend the vessel's service life, thereby ensuring it can continue to support the Indonesian Navy's operational requirements effectively and sustainably.

### NVivo Analysis Results

Qualitative data analysis was conducted using NVivo 12 Plus software to identify key themes emerging from interviews with informants involved in the operation, maintenance, and decision-making regarding the modernization of KRI X. The analysis involved coding, thematic categorization, and mapping relationships between variables related to the repowering program and the ship's operational readiness.

Word frequency analysis revealed that the most dominant terms appearing in the interviews were operation, ship, readiness, engine, propulsion, system, reliability, maintenance, repowering, and logistics. The prevalence of these terms indicates that informants viewed the condition of the propulsion system as a primary factor influencing the ship's operational readiness. Furthermore, the high frequency of terms such as reliability, maintenance, and repowering suggests significant concern regarding the sustainability of ship operations in the face of limitations posed by an aging propulsion system.

The analysis also demonstrated that the concept of operational readiness is influenced not only by the technical condition of the engines but also by various supporting factors, such as logistics support, spare parts availability, technical personnel capabilities, and the effectiveness of maintenance systems. These findings indicate that the challenges facing KRI X are multidimensional, requiring a comprehensive modernization approach. To understand the relationships between these factors, a project map analysis was conducted to visualize the connections among the key themes identified in the interviews. The mapping results showed strong links between variables such as propulsion system, engine performance, maintenance, repowering, and technical condition, and variables including unit readiness, ship speed, operational flexibility, endurance, operational deployment effectiveness, and deterrence capability. These relationships demonstrate that the condition of the propulsion system is a primary driver influencing the ship's overall operational capability.


Figure 1. Word Frequency Analysis Using NVivo 12 Plus.

An interesting finding from the mapping process is that the repowering factor is directly linked to almost all identified operational indicators. This indicates that informants view the repowering program as a strategic solution capable of enhancing engine performance, improving the technical condition of the propulsion system, increasing vessel reliability, extending operational endurance, and supporting the effectiveness of maritime operations. In other words, the benefits of repowering extend beyond technical performance improvements to positively impact the warship's combat readiness and deterrence capabilities.

Furthermore, the analysis reveals a strong relationship between logistics and maintenance support factors and both engine reliability and unit readiness. These findings indicate that the success of the repowering program depends not merely on replacing the engine or propulsion system, but also requires adequate supply chain support, spare parts availability, personnel competence, and robust maintenance systems. Without such support, the technical performance gains achieved through repowering might not be fully realized.

Overall, the NVivo analysis indicates that the decline in propulsion system performance is the primary factor behind the reduced operational readiness of KRI X. Conversely, the repowering program is perceived as a solution that positively influences system reliability, the effectiveness of operational deployment, mission flexibility, sailing endurance, and the warship's deterrence capabilities. Consequently, the NVivo analysis findings serve as the basis for identifying internal and external factors used to formulate a SWOT analysis, which in turn informs the development of the most suitable propulsion system modernization strategy for KRI X.

Word frequency analysis results indicate that the terms "operation," "ship," "readiness," "engine," "propulsion," and "reliability" are the dominant themes appearing most frequently in the interviews. This suggests a strong link between the condition of the propulsion system and the operational readiness and effectiveness of KRI X's operations.

**SWOT Analysis of the Repowering Program**

The SWOT analysis conducted in this study serves not only to identify factors influencing the repowering program but also to provide an overview of the organization's readiness to implement propulsion system modernization. The findings indicate that the majority of weaknesses facing KRI X stem from technical aspects related to the condition of the existing propulsion system, whereas the available opportunities largely arise from external factors specifically modernization policies, technological advancements, and escalating operational requirements. This situation suggests that the primary challenge lies not in a lack of need or support for modernization, but rather in the organization's capacity to overcome technical limitations that have accumulated over the vessel's service life.

These findings align with the NVivo analysis, which reveals a high degree of interconnectedness among themes such as engine reliability, maintenance, logistics support, unit readiness, and repowering. This indicates that the decline in the vessel's operational readiness is not attributable to a single factor but results from the interplay of various technical and operational elements. Consequently, the formulated modernization strategy cannot focus solely on replacing engines or propulsion components; it must also encompass the strengthening of support systems to ensure the sustainability of vessel operations following the completion of the repowering process.

Furthermore, the SWOT weighting results indicate that opportunity factors carry greater weight than threat factors. This reflects a strategic environment that is generally conducive to the implementation of the repowering program. Support for defense equipment modernization policies, growing maritime operational demands, and the availability of more efficient propulsion technologies offer the Indonesian Navy an opportunity to revitalize vessels that retain significant operational value. However, these opportunities can only be fully realized if internal weaknesses specifically those concerning propulsion system degradation, logistics support, and maintenance are addressed systematically.

Thus, the SWOT analysis indicates that the repowering program for KRI X is not merely a technical necessity to replace an aging propulsion system, but also a strategic imperative for maintaining the vessel's operational readiness in support of Koarmada II operations. These findings reinforce the argument that propulsion system modernization should be viewed as part of a sustained effort to enhance operational capabilities and maritime deterrence.

The SWOT analysis yielded an internal factor score of -0.23 and an external factor score of 0.31. This places the repowering program in Quadrant III, corresponding to the Weaknesses–Opportunities (WO) strategy. This position indicates that the organization has significant external opportunities for modernization but still faces various internal weaknesses that must be addressed first. Therefore, the most appropriate strategy is to leverage available modernization opportunities to rectify internal weaknesses in the propulsion system, which has suffered degradation due to the vessel's operational age.

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TABLE 1. INTERNAL FACTOR ANALYSIS SUMMARY (IFAS)

| No. | Factor | Weight | Rating | Weighted Score |
|---|---|---|---|---|
| ***Strengths*** | | | | |
| 1. | KRI X still holds strategic value in supporting the operations of the 2nd Fleet Command (Koarmada II). | 0.22 | 3.0 | 0.66 |
| 2. | Repowering has the potential to enhance the reliability of the propulsion system. | 0.18 | 3.1 | 0.55 |
| 3. | Repowering supports enhancing the operational effectiveness of the 2nd Fleet Command (Koarmada II). | 0.22 | 2.7 | 0.6 |
| 4. | The ship's crew has extensive experience in operating the existing propulsion system. | 0.17 | 2.7 | 0.46 |
| 5. | Repowering can enhance asset readiness. | 0.2 | 2.85 | 0.57 |
| | | | **Total** | **2.84** |
| ***Weaknesses*** | | | | |
| 1. | The ship and propulsion system are quite old. | 0.21 | 3.4 | 0.71 |
| 2. | The main engine performance is experiencing damage and degradation. | 0.19 | 3.0 | 0.57 |
| 3. | The gearbox and CPP systems are experiencing technical problems. | 0.21 | 3.0 | 0.63 |
| 4. | Maintenance requirements are increasing. | 0.2 | 2.7 | 0.54 |
| 5. | Limited spare parts and supporting materials. | 0.19 | 3.28 | 0.62 |
| | | | **Total** | **3.07** |

TABLE 2. EXTERNAL FACTOR ANALYSIS SUMMARY (EFAS)

| No. | Factor | Weight | Rating | Weighted Score |
|---|---|---|---|---|
| ***Opportunities*** | | | | |
| 1. | There is a need to modernize the Indonesian Navy's defense equipment. | 0.2 | 3.1 | 0.62 |
| 2. | Repowering offers an alternative to building new ships. | 0.205 | 3.7 | 0.75 |
| 3. | Support from the defense industry and domestic shipyards is available. | 0.19 | 3.4 | 0.64 |
| 4. | Operational requirements in the 2nd Fleet Command (Koarmada II) area of operations are increasing. | 0.2 | 3.6 | 0.72 |
| 5. | Repowering can enhance deterrence capabilities. | 0.195 | 3.6 | 0.7 |
| | | | **Total** | **3.43** |
| ***Threats*** | | | | |
| 1. | Risks of changes in defense budget policy | 0.21 | 3.3 | 0.69 |
| 2. | Risks of integrating new engines with legacy systems. | 0.19 | 2.7 | 0.51 |
| 3. | Risks of increased downtime during the repowering process. | 0.21 | 2.8 | 0.58 |
| 4. | Reliance on manufacturer and vendor support. | 0.19 | 3.3 | 0.62 |
| 5. | Risks of procurement delays. | 0.2 | 3.1 | 0.62 |
| | | | **Total** | **3.02** |

**Strategy for Propulsion System Modernization Through Repowering**

The primary weakness facing KRI X stems from the degradation of its propulsion system due to its long service life. Declining main engine performance, increased maintenance requirements, issues with the gearbox and Controllable Pitch Propeller (CPP) systems, and a scarcity of spare parts indicate that the existing propulsion system can no longer optimally support operational needs. Conversely, the Indonesian Navy's defense equipment modernization program, advancements in more efficient propulsion technology, and support from the national defense industry present a significant opportunity for modernization through a repowering program.

The proposed WO strategy focuses on replacing the underperforming propulsion system with technology that is more modern, efficient, and reliable. Implementing this repowering initiative is expected to enhance propulsion system reliability, reduce the frequency of breakdowns, improve fuel efficiency, and extend the vessel's operational lifespan. Thus, the repowering program offers a more cost-effective solution than constructing a new vessel, while simultaneously preserving the strategic value of KRI X in supporting the operations of the 2nd Fleet Command (Koarmada II).

In addition to equipment modernization, the WO strategy also emphasizes the importance of strengthening logistics and maintenance support systems. Spare parts availability, improved supply chain capabilities, and the development of

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maintenance facilities are necessary to ensure the operational sustainability of the new propulsion system. Adequate logistics support will reduce the risk of downtime and increase the long-term readiness of elements.

Human resources are also a critical factor in the success of repowering. Therefore, training programs, technology transfer, and competency improvement of technical personnel need to be implemented continuously so that crew members are able to operate and maintain the new propulsion system optimally. This step will accelerate the technology adaptation process while reducing the risk of operational disruptions during the transition period.

These findings align with Baldi et al. (3), Mou et al. (10), and Liu et al. (12), who explain that propulsion system modernization can improve operational efficiency and ship reliability when supported by an effective maintenance system. Therefore, the success of a repowering program is determined not only by engine replacement but also by the organization's readiness to manage technological change comprehensively.

Overall, the WO strategy is the most realistic and appropriate strategy to implement on the KRI X. Utilizing available modernization opportunities is expected to address the internal weaknesses of the propulsion system, thereby increasing operational readiness, operational effectiveness, and the deterrence of warships in a sustainable manner.

Based on repowering studies on similar ships conducted by Yuarizky et al. (7), Mou et al. (10), Liu et al. (12), and Liu et al. (16), modernizing the propulsion system on ships entering the aging fleet phase has the potential to increase energy efficiency, reduce fuel consumption, improve propulsion system reliability, and extend the ship's operational life. This increased reliability will result in increased operational availability, reduced need for corrective maintenance, and increased effectiveness in the use of maintenance resources. Thus, the implementation of repowering on KRI X is expected not only to enhance operational readiness but also to strengthen the vessel's operational sustainability in the long term.

This study has limitations as it focused on a single warship and involved a limited number of informants; consequently, the findings cannot be generalized to all types of KRI vessels. Future research could employ a quantitative approach to analyze the technical impact of repowering on performance parameters such as engine power, fuel consumption, vessel speed, and operational availability.

## IV. CONCLUSIONS

This study reveals that the propulsion system of KRI X has experienced significant performance degradation due to its operational life exceeding its design lifespan. Pre-Overhaul Test and Inspection (POT&I) results indicate performance declines in the main engine, gas turbine, gearbox, and controllable pitch propeller (CPP) system, all of which have compromised the propulsion system's reliability. This condition has diminished the vessel's ability to generate optimal thrust, thereby affecting its operational speed, maneuverability, cruising endurance, and overall operational readiness. NVivo analysis identifies propulsion system condition, engine reliability, maintenance, logistics support, and the repowering program as key factors influencing the vessel's operational readiness. These findings demonstrate that enhancing operational readiness depends not only on the technical aspects of the propulsion system but also requires adequate logistics support, maintenance systems, and organizational readiness.

Based on the SWOT analysis, the repowering program falls into the Weaknesses–Opportunities (WO) quadrant or a "Turn-Around Strategy" indicating significant external opportunities for modernization despite existing internal weaknesses in the propulsion system. Primary weaknesses stem from the system's advanced age, declining engine performance, increasing maintenance requirements, and spare parts shortages; conversely, key opportunities arise from defense equipment modernization programs, advancements in propulsion technology, and growing operational demands within the Koarmada II region.

The recommended strategy is to leverage available modernization opportunities to address internal weaknesses through the implementation of a repowering program. This strategy entails replacing the degraded propulsion system, strengthening logistics support and maintenance, and enhancing human resource competence through training and technology transfer. Successful implementation is expected to improve propulsion system reliability, reduce maintenance needs, increase operational efficiency, and extend the vessel's service life. Thus, the repowering program serves as an effective and economical modernization alternative to support enhancing the operational readiness of KRI X. Beyond its technical benefits, the program also contributes to improved operational deployment effectiveness and the sustainability of the Indonesian Navy's force development amidst the challenges posed by an aging fleet.

## REFERENCES

[1] G. Till, Seapower: A Guide for the Twenty-First Century, 5th ed. London, United Kingdom: Routledge, 2024.

[2] A. F. Molland, The Maritime Engineering Reference Book, 2nd ed. Oxford, United Kingdom: Butterworth-Heinemann, 2017.

[3] F. Baldi, F. Ahlgren, F. Melino, C. Gabrielii, and K. Andersson, "Optimal load allocation of complex ship power plants," Energy Conversion and Management, vol. 124, pp. 344–356, 2016.

[4] M. Stopford, Maritime Economics, 3rd ed. London, United Kingdom: Routledge, 2009.

[5] United Nations Conference on Trade and Development (UNCTAD), Review of Maritime Transport 2024. Geneva, Switzerland: United Nations Publications, 2024.

[6] K. Wróbel, J. Montewka, and P. Kujala, "Safety and reliability of ship systems," Reliability Engineering & System Safety, vol. 212, p. 107646, 2021.

Volume 10, Number 03, Page 903-910
e-ISSN: 2598-120X; p-ISSN: 2598-117X

[7] M. Yuarizky, A. Prasetyo, and B. Nugroho, “Analysis of the effect of repowering on ship engine performance,” Jurnal Teknik Perkapalan, vol. 9, no. 1, pp. 45–52, 2021.
[8] A. Prayitno, S. Hadi, and M. Kurniawan, “Warship maintenance strategy to enhance operational readiness,” Jurnal Teknologi Maritim, vol. 15, no. 2, pp. 85–94, 2021.
[9] D. Feng, H. Yang, and L. Wang, “Assessment of naval vessel modernization strategies under operational uncertainty,” Ocean Engineering, vol. 266, p. 112749, 2023.
[10] J. Mou, C. Ligteringen, and H. Xu, “Study on ship propulsion efficiency and energy-saving technologies,” Journal of Marine Science and Engineering, vol. 8, no. 6, pp. 1–18, 2020.
[11] H. Kim, J. Lee, and D. Shin, “A framework for predictive maintenance of naval propulsion systems using reliability analysis,” Journal of Marine Science and Engineering, vol. 10, no. 3, pp. 1–15, 2022.
[12] B. Liu, Y. Chen, and X. Zhou, “Integrated propulsion system optimization for naval ship operational efficiency,” Journal of Marine Engineering and Technology, vol. 23, no. 1, pp. 15–29, 2024.
[13] F. Rangkuti, SWOT Analysis: Techniques for Dissecting Business Cases. Jakarta, Indonesia: Gramedia Pustaka Utama, 2018.
[14] J. W. Creswell and J. D. Creswell, Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, 5th ed. Thousand Oaks, CA, USA: Sage Publications, 2018.
[15] M. Q. Patton, Qualitative Research and Evaluation Methods, 4th ed. Thousand Oaks, CA, USA: Sage Publications, 2015.
[16] B. Liu, Y. Chen, and H. Wang, “Reliability-centered maintenance for naval propulsion systems based on operational readiness assessment,” Ocean Engineering, vol. 287, p. 115823, 2024.
[17] H. Kim and D. Shin, “Predictive maintenance framework for marine propulsion systems using reliability and condition monitoring,” Journal of Marine Science and Engineering, vol. 11, no. 7, pp. 1–19, 2023.
[18] International Maritime Organization (IMO), Fourth IMO Greenhouse Gas Study 2020. London, United Kingdom: International Maritime Organization, 2021.