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Optimization Of Kri Maintenance in the Refurbishment Program to Support Improving the Readiness of Defense Equipment

Yudi Handoko [#1], Eko Arie Kurniawan[#2], Richard Martogi Pardede[#3]

[#] *Strategi Operasi Laut, Politeknik Angkatan Laut*
Ciledug Raya Street No.2, Seskoal, South Jakarta, DKI Jakarta, Indonesia 12230
yudihandoko2002@gmail.com

Abstract *— This research examines the optimization of KRI (Republic of Indonesia Navy Ships) maintenance in the Refurbishment Program to support the readiness of defense equipment (Alutsista). The study aims to provide an overview and solutions to the challenges faced in the refurbishment program as an effort to accelerate the enhancement of Alutsista readiness, given the current aging condition of KRIs and budget constraints. The research is based on optimization theory, refurbishment theory, and defense equipment readiness theory. The study employs a descriptive qualitative method using tools Nvivo 12 and SWOT analysis, with data collected through interviews and literature reviews. The findings highlight several key issues in the refurbishment program, including frequent equipment damage, limited budget availability, ship automation and digitalization, declining performance of sensor and navigation systems, and human resource and technological constraints. While current human resources and supporting technology are capable of implementing refurbishment planning and execution, maintenance systems often fail to adhere to schedules due to hindering factors such as extensive coordination gaps, budget limitations, reliance on imported components, and technological restrictions. The study concludes that maintenance conditions, import dependency, and technological limitations in the refurbishment program can be addressed through improved coordination, adoption of new technologies, KRI identification, life cycle-based approaches, integration of technical efficiency, workforce optimization, and stakeholder synergy.*

Keywords — *Maintenance, Optimalization, Refurbishment, Alutsista Readiness, Budget Constraints*

I. INTRODUCTION

The readiness of the Main Weapons System (Alutsista) is a strategic factor that determines a country's ability to defend sovereignty and maintain national security stability. In the context of maritime defense, the Republic of Indonesia Warship (KRI) plays a vital role as the spearhead of naval power in carrying out military operations, enforcing maritime law, and protecting natural resources and strategic trade routes that traverse Indonesian waters.[1] As the world's largest archipelagic nation with more than 17,000 islands and vast territorial waters, Indonesia relies heavily on the high readiness of its KRI to ensure the effectiveness of its maritime operations. An optimal level of KRI readiness is a key prerequisite for the success of the Indonesian Navy in carrying out defense operations, both in peacetime and in crisis situations, and serves as a symbol of the nation's existence and sovereignty at sea. However, the current state of KRI operational readiness still faces various complex challenges.[2] A number of internal and external factors influence the Navy's ability to maintain the performance of its warships to ensure their combat readiness and reliability. Limited maintenance budgets are often a major obstacle, where the allocation of funds for ship maintenance and repairs has not been able to keep up with the high level of wear and tear and operational needs.[3][4] Furthermore, dependence on imported spare parts and technology often hampers the maintenance process due to external factors such as supply delays, exchange rate fluctuations, and export regulations from supplier countries. Furthermore, technical human resource (HR) competency also needs to be improved, particularly in the face of increasingly complex and digitally integrated developments in modern warship technology.[5]

Although the macroeconomic trend in financial reporting quality shows improvement, at the operational level, this situation is exacerbated by the dynamics of the global and regional strategic environment, which demands rapid, efficient, and adaptive improvements to defense equipment capabilities. Competition for maritime power in the Indo-Pacific region, the increasing potential for maritime resource conflicts, and the

intensity of territorial violations by foreign vessels require the Indonesian Navy to maintain the readiness of its fleet.[6] However, efforts to modernize warships are often hampered by lengthy bureaucratic processes, contract delays, and mismatches between technical planning and actual conditions on the ground. As a result, several warships experience a decline in operational performance before reaching their ideal service life, which ultimately impacts the effectiveness of maritime operations and overall combat readiness.[7] To address these issues, the refurbishment program for warships is a key strategy undertaken by the Indonesian Navy and the Ministry of Defense. This program aims to extend the ships' service life, improve critical systems such as propulsion, navigation, and weapons, and adapt the ships' capabilities to the demands of modern operations without incurring the costs of procuring new ships. The refurbishment approach is considered an efficient solution in the context of budget constraints and the need to maintain the sustainability of defense equipment. However, in practice, the implementation of this program often faces obstacles such as a mismatch between the Scope of Work (SoW) and the actual condition of the ship, delays in contract activation due to foreign funding mechanisms, and weak cross-agency coordination between implementing parties, suppliers, and users.

The impact of these various problems is a decline in the operational readiness of KRI ships, which directly affects the Indonesian Navy's ability to maintain national maritime security. Ships that should be able to operate for patrols or strategic missions are often delayed due to inefficient repair processes.[8][9] This not only reduces the effectiveness of the Navy's main tasks but also has the potential to reduce Indonesia's deterrence effect in strategic maritime areas. Therefore, efforts are needed to optimize the implementation of the refurbishment program to be able to comprehensively address technical, administrative, and managerial challenges.[10] This optimization must include aspects of planning, implementation, evaluation, and synergy between the institutions involved so that KRI maintenance can be carried out effectively, efficiently, and sustainably. Based on this background, this study aims to analyze the implementation of KRI maintenance in the ongoing refurbishment program, identify inhibiting factors that affect the program's success, and formulate maintenance optimization strategies that can be applied to improve the readiness of the Indonesian Navy's defense equipment. Through this study, it is hoped that a deeper understanding of the effectiveness of the defense equipment maintenance system within the Indonesian Navy will be obtained, as well as providing theoretical contributions to the development of efficiency- and reliability-based maintenance concepts. In addition, the results of this study are expected to be a practical reference for policy makers within the Ministry of Defense and the Indonesian Navy in formulating strategic policies that are able to strengthen the operational readiness of KRI in a sustainable manner, while also supporting the independence of the national defense industry in the long term.

II. METHOD

Penelitian This research uses a qualitative approach with an exploratory case study design, aiming to analyze the maintenance strategy of the Republic of Indonesia Warships (KRI) during the refurbishment program. This approach was chosen because it allows for in-depth and contextual exploration of the phenomenon, particularly in understanding the dynamics of maintenance implementation and the factors influencing the program's effectiveness. Data were obtained through in-depth interviews with key informants, including Indonesian Navy officers with experience in ship maintenance and refurbishment program implementation. To enhance the validity of the research results, data triangulation was conducted by comparing the interviews, field observations, and relevant official documents. the unit of analysis in this study covers two levels: the organization and the individual. At the organizational level, the analysis focuses on institutions with authority and direct involvement in KRI maintenance and refurbishment activities, including the Defense Facilities Agency of the Ministry of Defense (Baranahan Kemhan), the Indonesian Navy Logistics Staff (Slogal), the Indonesian Navy Material Service (Dismatral), and the Marine Sector Division of the Defense Equipment Center of the Baranahan Kemhan. Meanwhile, at the individual level, the unit of analysis focuses on the implementation of the refurbishment program as part of efforts to improve the readiness of defense equipment. This approach allows researchers to understand the specific interactions and processes among actors within the institutional context of defense.

The data sources in this study consist of primary and secondary data. Primary data were collected through in-depth interviews with field technicians and refurbishment program implementing officials, as well as through participant observation of ship maintenance activities. Informants were selected using purposive sampling based on their experience, position, and direct involvement in program implementation. Secondary data were also obtained from official archives, organizational documents, academic literature, regulations, and publications related to defense equipment maintenance systems and defense modernization strategies. in this qualitative study, the researcher acted as the primary instrument, actively collecting, interpreting, and verifying data. Supporting instruments used included interview guidelines with open-ended questions and field observation guidelines. Data quality was maintained through the application of the principles of credibility, dependability,

and confirmability, achieved through triangulation and member checking. The data collection process involved three main techniques: observation, interviews, and literature review. Observations were conducted to understand behavioral patterns and activities related to the refurbishment program within the Ministry of Defense and the Indonesian Navy. Interviews were conducted with several key officials, including the Secretary of the Ministry of Defense's Baranahan, Paban II Mat Slogal, the Head of the Sub-Disteknokap, and the Head of the Maritime Division of the Ministry of Defense's Baranahan. Literature reviews were conducted on various academic references, regulations, and previous research results to strengthen the theoretical foundation.

The collected data was processed using NVivo 12 software, which assisted in coding, categorization, and visualization of relationships between themes.[11][12] This application was used to compile thematic patterns emerging from interviews and observations and to improve the accuracy of triangulation between data sources. In addition to thematic analysis, a SWOT analysis approach was also used to identify strengths, weaknesses, opportunities, and threats in the implementation of the refurbishment program, allowing for the formulation of applicable KRI maintenance optimization strategies.[13][14]The data analysis process followed the Miles and Huberman model, which includes four stages: (1) data collection, (2) data reduction by selecting relevant information, (3) data presentation in matrix form and visualization of NVivo results, and (4) drawing conclusions and verification based on the interpretation of the findings. Through these stages, this research is expected to yield a comprehensive understanding of the dynamics of KRI refurbishment implementation and an effective and sustainable maintenance management strategy to support the readiness of the Indonesian Navy's defense equipment.

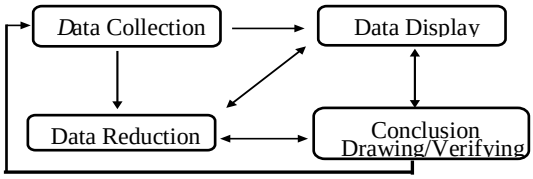

Fig. 1 Components in Data Analysis

III. Results And Discussion

A. Data Processing with NVivo 12.

The next stage involves inputting the interview results into NVivo software, which then undergoes a coding process. Although the questions asked are the same, informants often provide diverse answers, and this can be identified through the coding results. This process also includes data triangulation, which aims to demonstrate the informants' focus on a particular topic. the collected data is then coded and grouped based on relevant major themes. Each node or category resulting from this process is developed inductively, based on the interviews conducted and the field notes recorded by the researcher

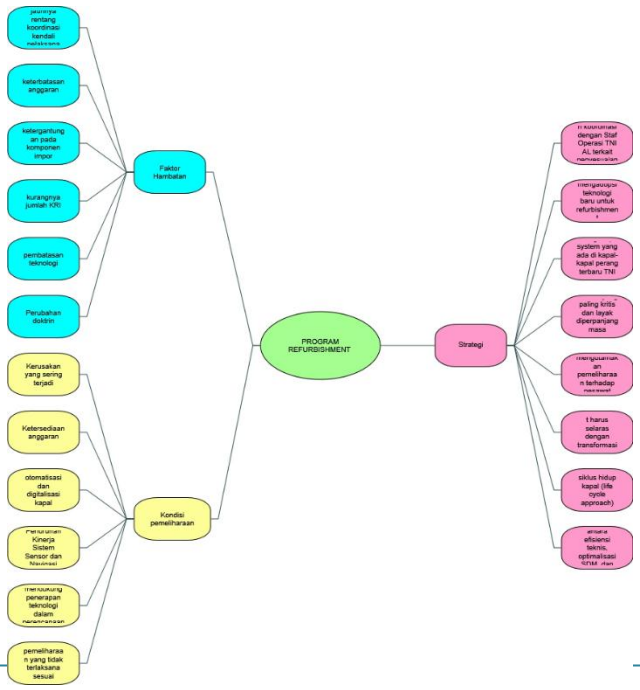

Fig. 2 Research Process Mind Map

The NVivo analysis revealed several key interrelated themes, particularly in the context of KRI maintenance, constraints, and the Indonesian Navy's strategy for KRI. The following are the key points identified:

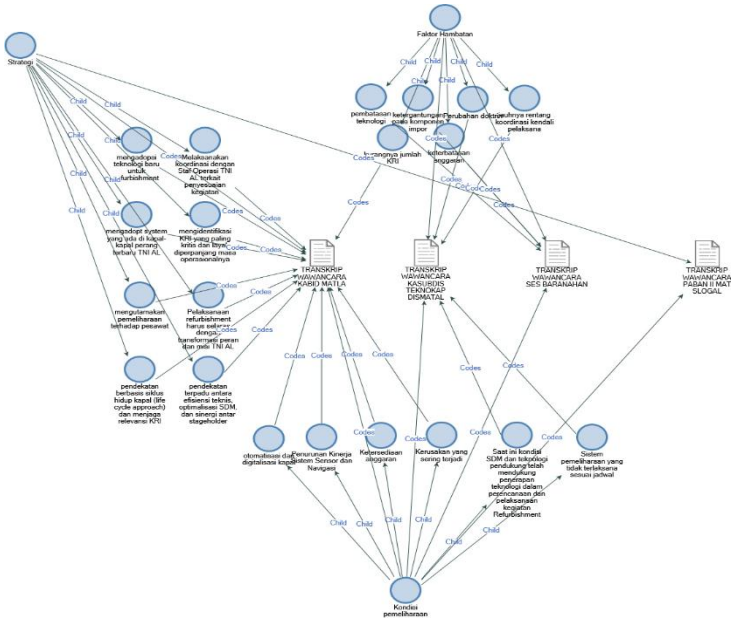

Fig. 3 Triangulation of Research Process

B. Grouping of Research Data Results.

1. Maintenance Conditions. The findings of this study indicate that the KRI's maintenance system significantly influences its readiness, which demands adoption of technological developments in a scheduled maintenance system.
2. Obstacles. The implementation of the refurbishment program encountered several obstacles that disrupted its implementation, particularly due to budget constraints. Importing goods and equipment from manufacturing countries, which requires a long lead time, is a direct result of the rapidly changing global strategic environment.
3. Strategy. Data from the literature review and interviews with key informants provide solutions to address the problems arising from the refurbishment program through synergy between stakeholder agencies for coordination, communication, and commitment.

C. Data Processing with SWOT Analysis

1. Internal Factors (IFAS)
   a. Strength
      1) Trained Human Resources (HR). The availability of personnel with technical expertise in ship maintenance and refurbishment.
      2) Supporting Facilities and Infrastructure. The availability of dockyards, workshops, and specialized equipment for ship repairs.
      3) Experience in Refurbishment Programs. Previous experience upgrading older ships to more modern ones.
      4) Budgetary Support from the Government. The allocation of special funds for the maintenance and modernization of the Indonesian Navy's defense equipment.
   b. Weaknesses

1) Budgetary Constraints. Insufficient funds for optimal maintenance and spare parts procurement.
2) Dependence on Imported Spare Parts. Reliance on imported components impacts repair times.
3) Lack of Cutting-Edge Technology. Refurbishment facilities and methods are not yet fully modern.
4) Slow planning and execution processes due to complex bureaucracy

2. External factors (EFAS)
   a. Opportunities
      1) Cooperation with the Local Defense Industry. Collaboration with PT PAL Indonesia and the domestic industry for spare parts and technology.
      2) Technology Transfer from Partner Countries. Opportunities for collaboration with other countries to increase refurbishment capacity.
      3) Supportive Government Policies. The "Alutsista Independence" program encourages the strengthening of the national defense industry.
      4) Increasing Maritime Security Threats. The need for operationally ready Indonesian warships (KRI) drives the priority of refurbishment.
   b. Threats
      1) Rapid Adversary Technological Development. The constantly evolving capabilities of other countries' defense equipment require faster updates.
      2) Sanctions or Import Restrictions. The risk of disruptions to the supply of spare parts from abroad due to geopolitical conflicts.
      3) Changes in Defense Policy. Shifts in defense budget priorities may reduce the focus on refurbishment.
      4) Environmental Conditions That Accelerate Deterioration. Seawater corrosion and extreme weather factors shorten the technical lifespan of KRI vessels

From the results of the analysis carried out on external and internal factors, the values obtained can be summarized as follows:

1. Strengths = 0,75
2. Weaknesses = 0,40
3. Opportunities = 1,20
4. Threats = 1,65

Based on the results of the SWOT analysis that has been carried out, the position of the total value of internal factors (Strengths + Weaknesses = 0.75 + (-0.40) = 0.35) and the total value of external factors (Opportunities + Threats = 1.20 + (-1.65) = -0.45), then the results of the analysis are in Quadrant II in the SWOT Matrix. The description of the Quadrant II position is diversification so that the strategy used is Defensive / Turnaround which indicates that Internal Factors are relatively stronger (positive value 0.35), but external factors tend to be threatening (negative value -0.45). External threats (1.65) are more dominant than opportunities (1.20), while internal strengths (0.75) are not strong enough to fully offset weaknesses (0.40)

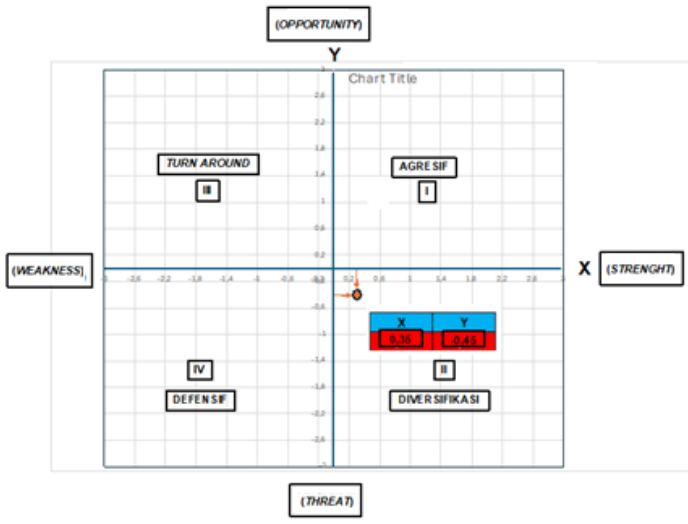

Fig. 3 SWOT calculation quadrant

Strategic Implications: The Indonesian Navy (KRI) refurbishment program faces high risks due to external pressures, necessitating a defensive or turnaround approach. This includes minimizing reliance on threats. For example, if the primary threat is a disruption in the supply of imported spare parts, diversifying suppliers or accelerating the development of the domestic defense industry is the solution. Address internal weaknesses to address threats by increasing maintenance budget efficiency, optimizing human resources, or adopting technologies that reduce reliance on external factors. Leverage existing strengths, if these strengths lie in human resource skills, by utilizing the expertise of local experts to repair KRIs with limited resources. Examples of concrete actions taken include increasing logistical independence through collaboration with defense state-owned enterprises (PT PAL, PT Pindad, etc.). Strengthen geopolitical risk mitigation by preparing backup scenarios for critical spare parts. Optimize the refurbishment program by focusing on components that most impact operational readiness. Based on interviews with research informants, the results of discussions analyzing the current state of KRI maintenance, the obstacles to refurbishment, and potential refurbishment optimization strategies are presented as follows:

1. Paban II Mat Slogal stated that the current maintenance conditions for the KRI are still suboptimal, resulting in frequent equipment failures, particularly in the propulsion system, diesel generator, air conditioner, and sometimes navigation equipment, requiring innovative maritime technology. Given the limited budget and resources available, it is hoped that the refurbishment can be carried out effectively and efficiently to meet operational needs.
2. The Secretary of the Ministry of Defense's Baranahan believes that the refurbishment must utilize new technologies, for example, the installation of Active Electronically Scanned Array (AESA) and Sonar Array for more accurate detection. In terms of budget and resources, consideration must be given to the cost of imported components. This will ensure resource efficiency through optimizing the local supply chain, training domestic technicians to reduce dependence on foreign vendors, and utilizing digital simulations to minimize errors during the refurbishment process.
3. The Head of the Sub-Disteknokap Dismatal (National Maritime Affairs and Fisheries Service) conveyed the usefulness of automation technology for detecting the technical condition of machinery and aircraft to support ship operations, representing an innovative technological breakthrough in refurbishment that impacts the accuracy of planning, implementation, and lifespan of equipment/machinery in the ship maintenance process. Budgetary factors must also be taken into account in refurbishment, including the procurement of spare parts and machinery, as well as maintenance service costs. Efficient budget utilization in the refurbishment process can be achieved by implementing procurement technology (e-purchasing) in the selection of goods and services providers to ensure efficient resource utilization.
4. The Head of the Maritime Division stated that damage to the KRI (Indonesian Maritime Ship) typically occurs in moving parts of the aircraft/equipment, including damage to the propulsion system (engine and gearbox), electrical system and control panel problems, hull damage, decreased sensor and navigation system performance, and damage to the weapons system. IT technology and the use of applications are highly feasible in KRI maintenance. The availability of maritime technology in the form of applications can help ensure the smooth implementation of refurbishment activities. That in terms of budget availability and speed in the effectiveness of the contract, it has a big influence on the implementation of refurbishment so that the speed of the effective contract influences the effectiveness and efficiency of the implementation of refurbishment.

Kelly and Mobley's Maintenance Theory, which divides maintenance into preventive, corrective, predictive, and proactive, directly addresses the first problem statement regarding the current state of KRI maintenance. Meanwhile, Ashworth's Refurbishment Theory expands the analysis by emphasizing that KRI rejuvenation is not merely a physical repair, but also includes system modernization. The Defense Equipment Readiness Theory complements the analysis by emphasizing aspects of human resources, logistics, and system integration, which are directly related to the second problem statement regarding factors inhibiting maintenance optimization. For example, the lack of experts and coordination between institutions (such as the Ministry of Defense and the Ministry of Finance) is in accordance with the Defense Equipment readiness indicators that require the availability of trained human resources and efficient logistics management. Furthermore, Taha and Winston's Optimization Theory provides a framework for formulating problem-solving strategies (the third problem statement), such as appropriate budget allocation, refurbishment priorities based on urgency, and the use of technology for efficiency.

D. Discussion

Indonesia (KRI) is in Quadrant II (Diversification), indicating that internal strengths outweigh weaknesses, but external threats still outweigh opportunities. This reflects the Indonesian Navy's strong internal potential, such as experienced human resources, supporting facilities, and a sufficient budgetary base. However, it still faces constraints such as import dependence, lengthy bureaucracy, and limited technology and inter-agency coordination. Maintenance Condition. KRI maintenance is a vital aspect in maintaining the operational readiness of defense equipment. Various obstacles such as engine and navigation system failures, and irregular maintenance schedules often hamper operational effectiveness. Budget constraints lead to selective repairs, while the use of modern technologies such as digital monitoring, real-time sensors, and automation remains limited. Meanwhile, the technical competence of maintenance personnel has shown positive potential, but needs to be improved through technology-based training to support the implementation of predictive maintenance systems and digital twins.

Barriers. The main obstacles to program implementation include a lack of cross-agency coordination, budget constraints, reliance on imported components, and the limited number of operationally ready KRIs. The wide span of control between implementers and the multi-layered bureaucracy leads to delays in decision-making. Furthermore, changes in defense doctrine and technological limitations complicate the adaptation of ship systems to the demands of modern operations. This situation demands efficient governance, cross-functional synchronization, and strengthened support from the domestic industry. Policy. Government and Indonesian Navy policies have provided a strategic basis for the refurbishment program. Through Presidential Regulation No. 8 of 2021, the 2020–2024 Indonesian Navy Strategic Plan, and Law No. 16 of 2012 concerning the Defense Industry, the government emphasizes the importance of maintaining and modernizing defense equipment to extend the service life of the Indonesian Navy (KRI). A Life Cycle Management (LCM) policy is implemented to ensure a measurable and sustainable maintenance process, supported by collaboration between the Ministry of Defense, PT PAL Indonesia, and other national defense industries. Strategy and Optimization Efforts. The analysis indicates the need for an integrated defensive strategy to strengthen the readiness of the Indonesian Navy (KRI). Key strategies include:

1. Strengthening the domestic defense industry, through increased collaboration with PT PAL and the development of local technology to reduce dependence on imports and accelerate the refurbishment process.
2. Budget efficiency and human resource optimization, with a focus on vital components and advanced technical training.
3. Mitigating external threats, through supplier diversification, implementing a life cycle approach, and prioritizing ships with high strategic value.
4. Utilizing policy and technology opportunities, including integration with offset agreement programs for technology transfer and local innovation.

Practically, maintenance optimization can be achieved through the implementation of predictive maintenance, 3D printing for spare parts, big data analytics for ship performance evaluation, and cross-functional coordination between maintenance, operations, and logistics. With this approach, the refurbishment program not only extends the ship's service life but also strengthens maritime deterrence and supports sustainable national defense independence.

IV. Conclusion

The research results show that optimizing KRI maintenance during the refurbishment program is significantly influenced by various interrelated factors, including the ship's technical condition, budget constraints, human resource competency, and dynamic operational requirements. The ship's age, extreme maritime environments, and delayed maintenance contribute to the increasing level of damage to KRI. Furthermore, budget constraints and reliance on imported spare parts are major obstacles hampering the effectiveness of the refurbishment program.

Lack of coordination among stakeholders, including government agencies, the defense industry, and research institutions, also impedes maintenance efficiency. Furthermore, technological limitations and a shortage of technical experts hamper the modernization of warship systems. Therefore, a comprehensive, integrated, and sustainable maintenance strategy is needed to improve the operational readiness of the Indonesian Navy's defense equipment.

Improving human resource competency, efficient budget allocation, strengthening cross-agency coordination, and developing the independence of the national defense industry are key steps to support the success of the

refurbishment program. This will ensure KRI readiness continues to carry out maritime defense missions, while simultaneously strengthening Indonesia's deterrent power and maritime sovereignty.

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