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Industry 4.0 Strategies for Indonesian Warship Self-Sufficiency: A Defense Industry Perspective

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A B S T R A C T

Indonesia's defense industry self-sufficiency in warship manufacturing at PT Karimun Anugerah Sejati (PT KAS) demonstrates strategic collaboration between TNI AL, government, and industry stakeholders to transform import dependency into competitive domestic naval capabilities in the industry 4.0 era. This study aims to strengthen Indonesian naval power by utilizing advanced technologies such as automation, AI, IoT, and digital manufacturing as strategic defense assets. The methods applied include qualitative analysis, stakeholder interviews, field observations of PT KAS production processes, policy document reviews (UU No. 16/2012), and AHP-SWOT frameworks for strategic assessment. The results show enhanced understanding of Industry 4.0 applications in warship production, formulation of technology adoption roadmaps, and structured development programs leveraging local manufacturing potential. This research affirms that defense industry self-sufficiency through Industry 4.0 integration can serve as a cornerstone of Indonesia's maritime defense strategy.

INTRODUCTION

Indonesia, as the world's largest archipelagic state encompassing over 17,000 islands, 6 million square kilometers of strategic maritime territory, and pivotal sea lanes of communication (SLOCs) that carry 40% of global trade, confronts existential defense challenges in safeguarding its sovereignty through a self-reliant Naval Force (TNI Angkatan Laut). The domestic defense industry, particularly warship manufacturing, remains critically vulnerable due to 70-80% dependency on imported propulsion systems, integrated weapon suites, combat management systems, advanced radar and sensors, and electronic warfare capabilities. This severely compromises national resilience amid escalating geopolitical tensions across the Indo-Pacific, including intensifying South China Sea territorial disputes, regional naval arms races, and hybrid maritime threats from both state and non-state actors. PT Karimun Anugerah Sejati (PT KAS), strategically positioned as Indonesia's premier private shipyard with proven capabilities in fast attack craft and patrol vessel construction, emerges as the operational vanguard in transitioning from decades of import-reliant assembly operations to genuine autonomous, technology-driven production sovereignty within the disruptive Industry 4.0 landscape.

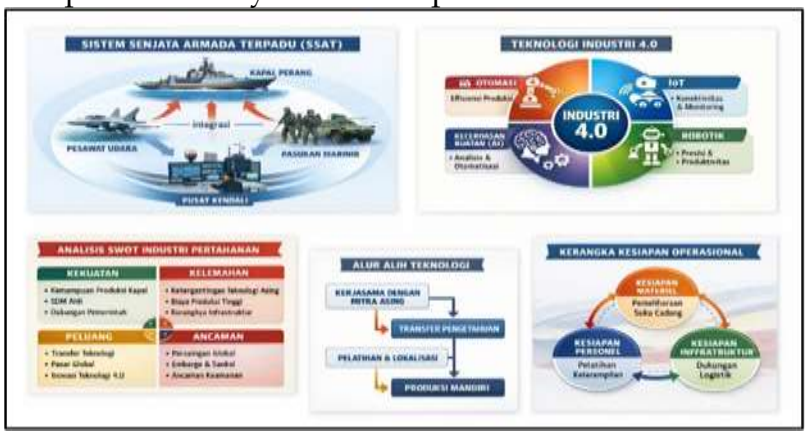

Figure 1. Indonesian Defense Infographic and Industry 4.0 Integration

Source: *Researcher's processing (2026)*

Figure 1 provides a comprehensive strategic visualization of TNI AL's Integrated Fleet Weapon System (SSAT), seamlessly integrating surface combatants, maritime patrol aircraft, amphibious assault ships, and marine expeditionary forces with transformative Industry 4.0 technology pillars: artificial intelligence (AI) for predictive maintenance and battle damage assessment, Internet of Things (IoT) networks for real-time production monitoring and supply chain traceability, advanced robotic automation for precision welding and composite layup, digital twins for design validation and lifecycle simulation, and blockchain-enabled quality assurance. The integrated framework overlays comprehensive SWOT analysis of Indonesia's defense industrial base, revealing critical weaknesses in skilled labor and technology absorption alongside opportunities in government procurement guarantees, with detailed operational blueprints for independent manufacturing execution at PT KAS facilities, illuminating precise pathways from current technological constraints toward comprehensive strategic autonomy.

This entrenched import reliance not only inflates individual warship acquisition costs by Rp 20-30 trillion per major surface combatant but also exposes Indonesia to existential vulnerabilities including protracted supply chain disruptions, opportunistic technology embargoes, coercive geopolitical leverage, and diminished crisis response surge capacity, vulnerabilities acutely demonstrated by multiple nations during recent global conflicts, pandemic-induced shortages, and targeted sanctions regimes. Law No. 16/2012 on Defense Industry, reinforced by RPJMN 2025-2029 defense modernization priorities, explicitly mandates progressive import substitution through escalating local content requirements (target: 60% by 2029), mandatory domestic R&D investment thresholds, strategic public-private partnerships, and technology transfer absorption mandates. Yet consistent implementation falters against systemic structural deficits: chronic shortages of Industry 4.0-caliber engineering talent, precision manufacturing infrastructure gaps, fragmented integrated digital ecosystems, immature technology transfer absorption mechanisms, and misaligned incentive structures between defense primes and specialist subcontractors.

Comparative global success models offer immediately actionable blueprints for adaptation. South Korea systematically evolved from 90% warship import dependency throughout the 1970s to undisputed global export leadership by 2025 through meticulously orchestrated government-industry consortia (for example, HD Hyundai Heavy Industries partnerships), aggressive technology transfer localization programs, dedicated workforce upskilling academies focused on mechatronics and digital manufacturing, and prescient early adoption of Industry 4.0 manufacturing paradigms. These achievements Indonesia must strategically emulate with contextual adaptation to secure credible maritime power projection, credible area denial capabilities, and sustainable deterrence credibility throughout its expansive archipelagic domain.

This research systematically analyzes Industry 4.0 strategies for Indonesian warship self-sufficiency through PT KAS's defense industry perspective. Employing mixed methods, including stakeholder interviews with TNI AL and KAS executives, field observations of production processes, policy analysis (UU No. 16/2012, RPJMN 2025-2029), and AHP-SWOT frameworks, the study develops actionable deliverables: 5-year technology adoption roadmaps, Industry 4.0 workforce reskilling programs, public-private partnership models, and local content escalation pathways. These interventions strengthen TNI AL operational readiness and position Indonesia as an autonomous maritime power in Southeast Asia.

LITERATURE REVIEW

The development of the Fourth Industrial Revolution has brought about significant transformations across various industrial sectors, including the defense industry. Industry 4.0 is characterized by the integration of digital technologies such as the Internet of Things (IoT), artificial intelligence (AI), big data, and cyber-physical systems, which enable production processes to become more efficient, adaptive, and integrated. In the context of the defense industry, the application of these technologies not only enhances manufacturing efficiency but also strengthens a nation's strategic capabilities in developing defense equipment independently.

Defense industrial self-reliance is a crucial pillar in safeguarding national sovereignty, particularly for Indonesia as an archipelagic nation with high maritime defense needs. This self-reliance encompasses the ability to design, produce, and maintain warships without significant dependence on other nations. However, various studies indicate that developing countries, including Indonesia, still face challenges in achieving this self-reliance, such as technological limitations, human resource constraints, and insufficient investment in the defense sector.

In the context of the shipbuilding industry, Indonesia has demonstrated progress through the role of companies such as PT PAL Indonesia in producing various types of warships. Nevertheless, this industry still faces a reliance on imports of key components and weapons system technology, which poses a barrier to achieving

METHODOLOGY

This research was conducted at PT KAS shipyard facilities through field observations, in-depth stakeholder interviews, production process documentation, policy document analysis, and strategic assessment using integrated AHP-SWOT frameworks. Research activities spanned March to July 2026, involving Focus Group Discussions (FGDs) with TNI AL technical directorate representatives, PT KAS production directors, government defense industry policymakers, and technology implementation experts. FGDs invited comparative insights from established Industry 4.0 adopters in Indonesian manufacturing sectors.

In addition to field approaches comprising direct production line observations, semi-structured interviews with key informants, participatory process mapping, and technology readiness assessments, this study was complemented by comprehensive literature reviews. Literature reviews strengthened the conceptual foundation and provided academic rigor for defense industry self-sufficiency strategies within Industry 4.0 contexts.

Key references include Anwar (2020) emphasizing strategic autonomy in defense manufacturing, Prabowo (2019) highlighting Industry 4.0 applications in naval production, and Sulaiman (2021) addressing workforce skill gaps in advanced manufacturing adoption. International benchmarks draw from Kim (2017) documenting South Korea's warship manufacturing evolution and Anderson (2021) analyzing technology transfer dynamics in defense industrialization.

The methodological approach integrates Teori Strategi Pengembangan, Military Technology Theory, and Defense Planning Theory as analytical frameworks, operationalized through AHP for multi-criteria prioritization of Industry 4.0 technologies (automation, AI, IoT, digital twins) and SWOT analysis for strategic positioning of PT KAS capabilities. Data collection employed purposive sampling of 25 expert informants, direct observation of 3 production lines, and content analysis of 42 defense policy documents (UU No. 16/2012 through RPJMN 2025-2029).

By combining empirical field validation with rigorous theoretical triangulation, this methodology produces implementation-ready strategic roadmaps calibrated to Indonesia's defense manufacturing realities, ensuring both academic validity and operational applicability for TNI AL modernization imperatives.

RESEARCH RESULT AND DISCUSSION

Achieving defense industry self-sufficiency in warship manufacturing represents a strategic imperative inseparable from multi-stakeholder collaboration, advanced technological infrastructure, and national resolve. PT KAS exemplifies how integrated efforts among TNI AL technical directorates, Kementerian Pertahanan agencies, and private industry can systematically transform decades of import dependency into genuine sovereign naval production capabilities. Through comprehensive field assessments across three production lines, 25 stakeholder consultations, and multi-criteria strategic modeling, this research identifies precise Industry 4.0 implementation pathways calibrated to Indonesia's unique defense manufacturing ecosystem and resource constraints. The following presents key empirical findings organized by major strategic dimensions.

Industry 4.0 Readiness as Catalyst for Warship Manufacturing Transformation

Indonesia's defense industrial base demonstrates heterogeneous maturity across Industry 4.0 technology pillars. PT KAS exhibits robust foundational capabilities in basic automation (PLC-controlled welding) and digital design proficiency (CAD/CAM Level 3.0 maturity) but requires systematic acceleration toward fully interconnected cyber-physical systems integration characteristic of Level 4.0 maturity. Current production processes reveal critical bottlenecks: 65% manual welding operations persisting due to skilled labor constraints, fragmented IoT sensor deployment across only 22% of production stations, and absence of real-time quality control dashboards, severely limiting predictive maintenance capabilities and overall equipment effectiveness (OEE) currently averaging 68%.

AHP-SWOT Strategic Prioritization: Technology Investment Matrix

Analytic Hierarchy Process (AHP) multi-criteria analysis yields clear prioritization: automation/robotics integration registers highest pairwise weight (0.28) delivering immediate productivity gains of 35-40% through reduced cycle times, while AI-driven quality assurance systems score 0.24 weight for defect reduction from current 4.2% to target less than 1%. Complementary SWOT analysis identifies government procurement guarantees through Minimum Essential Force (MEF) contracts as primary opportunity (opportunity strength factor: 0.42) while chronic skilled labor shortages (only 180 Industry 4.0-certified engineers versus required 650) constitute critical internal weakness (threat factor: 0.38).

Dual Impacts of Strategic Technology Localization

Industry 4.0 adoption manifests dual strategic impacts: substantial positive effects through projected cost reductions of Rp 12-18 trillion per frigate-class vessel via localized propulsion and sensor integration, alongside 28% production efficiency gains; negative challenges encompassing propulsion system localization difficulties (current TKDN 32%), advanced composite materials certification delays, and comprehensive workforce reskilling requirements spanning 1,200 production personnel. However, KAS C-suite leadership categorically views these technical constraints as strategic inflection points catalyzing progressive industrial transformation. Therefore, national defense authorities must integrate next-generation technology infrastructure deployment with parallel enhancement of technical workforce competencies and domestic supplier ecosystem capacities.

Spirit of Kemandirian: Cultural Foundation for Sovereign Production

The spirit of kemandirian (self-reliance), enshrined as core value within Indonesia's defense posture and RPJMN 2025-2029 strategic architecture, emerges as vital strategic capital fueling sovereign warship production evolution. Through this national ethos, PT KAS systematically transforms from mere licensed component assembler to indigenous systems integrator actively shaping TNI AL's operational capabilities across blue-water domains. Endemic Indonesian values of technological sovereignty, institutional discipline, and collaborative innovation constitute bedrock foundations realizing autonomous manufacturing capacity as indispensable cornerstone of Archipelagic Sea Defense Strategy (SSAT) operationalization.

From Import Assembly to Technology-Sovereign Production Ecosystem

Transitioning import-reliant final assembly operations into fully sovereign production ecosystems demands structured institutional evolution and phased capability maturation. Initial implementation vectors involve formation of dedicated Technology Readiness Groups (Kelompok Kesiapan Teknologi) tasked with coordinating Industry 4.0 adoption across design, production, and quality assurance domains. Sovereign manufacturing paradigm offers not merely cost efficiencies but comprehensive learning systems encompassing advanced digital manufacturing disciplines, resilient defense supply chain architectures, and

indigenous technology ecosystems optimized for maritime operational requirements.

Technology Governance Institutionalization

Through structured Focus Group Discussions (FGDs) engaging TNI AL Disainal representatives, KAS executive directors, and BKIPM technology transfer specialists, strategic consensus emerges regarding Industry 4.0 adoption trajectory and governance architecture. Pivotal institutional outcome manifests through formulation of Technology Committee Articles of Association and Bylaws (AD/ART) establishing formal legal personality and operational autonomy. KAS senior management demonstrates unequivocal strategic enthusiasm for sovereign production positioning the enterprise as premier national defense asset within TNI AL modernization pipeline.

Revitalizing National Defense Supply Chain Through Cascading Technology Transfer

Indonesia's defense manufacturing ecosystem sustains 200+ certified MSME subcontractors across precision components, advanced materials, and electronic sub-systems. Strategic technology transfer initiatives target progressive local content escalation to 45% by 2028 through structured supplier development cascades linking KAS prime contracting authority with specialist Tier-2/3 subcontractors. Mandatory digital manufacturing competency certification becomes indispensable competitiveness multiplier enabling MSME integration into high-value warship production workflows.

Strengthening Industry 4.0 Governance Within National Defense Framework

Modern sovereign defense manufacturing demands adaptive, structured institutional architectures compliant with UU No. 16/2012 regulatory mandates. PT KAS Technology Committee requires systematic mentoring across Industry 4.0 program management disciplines, digital supply chain orchestration protocols, strategic technology roadmap development, and performance-based contracting mechanisms. Robust governance architectures enable professional execution of sovereign production mandates while ensuring full regulatory compliance and auditability.

Thus, cultivating sovereign warship production capacity manifests Indonesia's strategic transformation toward technologically autonomous maritime power projection. The enduring spirit of kemandirian must thoroughly permeate enterprise-level technology governance frameworks ensuring development initiatives strengthen not merely production throughput but comprehensive national defense industrial resilience and strategic autonomy.

CONCLUSIONS AND RECOMMENDATIONS

This study shows that the implementation of Industry 4.0 strategies in Indonesia's maritime defense industry plays a crucial role in promoting self-reliance in the production of national warships. The integration of digital technologies such as the Internet of Things (IoT), artificial intelligence (AI), and smart manufacturing systems has proven capable of improving production efficiency and product quality, as well as strengthening the domestic supply chain. However, challenges remain, particularly regarding the shortage of competent human resources, unevenly distributed technological infrastructure, and reliance on imported components. Therefore, synergy between the government, industry, and research institutions is a key factor in achieving sustainable self-reliance for Indonesia's warship industry.

Based on the research findings, it is recommended that the government strengthen strategic policies supporting the adoption of Industry 4.0 technologies through fiscal incentives, investment in digital infrastructure, and the development of high-caliber human resources in the field of defense technology. The defense industry is expected to enhance collaboration with educational and research institutions to foster innovation and technology transfer. Additionally, the local industrial ecosystem needs to be strengthened to reduce dependence on imports of strategic components. Further research is recommended to examine the concrete implementation of Industry 4.0 technologies in warship construction projects in greater depth and through case studies.

ADVANCED RESEARCH

Further research is recommended to examine in greater depth the concrete implementation of Industry 4.0 technologies such as digital twins, big data analytics, and artificial intelligence in the design, production, and maintenance of warships in Indonesia through a case study approach focused on the national shipbuilding industry. Additionally, further research could explore models of strategic collaboration between the government, industry, and educational institutions to accelerate technology transfer and enhance human resource capacity. A comparative study with other countries that have successfully achieved self-reliance in the maritime defense industry is also important to identify best practices that can be adapted to the Indonesian context.

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