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MORALITY BEFORE KNOWLEDGE

Hexa-Helix collaboration model for strengthening the maritime defense industry in eastern Indonesia: A strategic policy analysis

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ABSTRACT

Background: Indonesia's position as the world's largest archipelagic state with vast maritime territory places it at the center of the Indo-Pacific region's complex geopolitical dynamics. Despite abundant marine resources, eastern Indonesia still struggles with uneven infrastructure, weak surveillance, and threats such as IUU Fishing and undersea sabotage. This article examines how the Hexa-Helix Collaboration Model-expanding beyond the traditional Triple Helix-can serve as an innovative governance framework to strengthen the maritime defense industry in eastern Indonesia, ensuring balanced development and adaptive resilience. **Method:** The analysis employs a qualitative literature review method, synthesizing global best practices and relevant case studies. Key topics include the implementation of smart port technologies, Digital Twin shipyard modernization, cybersecurity risk management, community empowerment, and regional security strategies aligned with the ASEAN Outlook on the Indo-Pacific. **Results:** The study finds that integrating government, military, academia, industry, local communities, and media fosters inclusive policy-making, enhances surveillance capabilities, promotes economic diversification in coastal villages, and bridges inter-agency coordination gaps. Practical recommendations include establishing a national Maritime Data Hub, adopting advanced subsea monitoring technologies, and ensuring that digital transformation aligns with human capital development. **Conclusion:** The Hexa-Helix Collaboration Model offers a practical, adaptive pathway for Indonesia to transform its eastern maritime regions into self-reliant defense and logistics hubs. By combining technological innovation, community participation, and evidence-based governance, Indonesia can realize its vision as a resilient Global Maritime Fulcrum amid intensifying Indo-Pacific competition. **Novelty/Originality of this article:** The novelty of this article lies in the application of the Hexa-Helix Collaboration Model as a governance framework for the maritime defense industry, an area rarely explored in Indonesian strategic studies.

Keywords: maritime security, Hexa-Helix, indo-pacific, smart port, subsea infrastructure.

1. Introduction

As the world's largest archipelagic country with the second-longest coastline globally, Indonesia possesses vast maritime territory that dominates most of its surface area, making the sea the lifeline that connects islands stretching from Sabang to Merauke. Geographically positioned between the Indian and Pacific Oceans, Indonesia holds a strategic advantage, as this location places the country along vital global trade routes. One of the key elements of this strategic role is the Indonesian Archipelagic Sea Lanes/*Alur Laut Kepulauan Indonesia*

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(ALKI), which serve as crucial transit routes for the distribution of goods, energy, and commodities across continents. However, the existence of ALKI not only brings economic opportunities but also poses significant challenges related to maritime security, regional stability, and geopolitical rivalry in the Indo-Pacific (Li et al., 2023). This perspective aligns with Mahan's classic theory (1890), which asserts that dominance over sea routes determines a nation's strength on the global stage.

In recent decades, the spectrum of threats faced by Indonesia's waters has shifted significantly. Previously, maritime security challenges focused more on traditional issues such as potential military conflict and territorial disputes. Now, new dimensions demand greater attention, including the protection of undersea communication cables, safeguarding energy supply chains, tackling transnational crimes, and countering cyberattacks targeting modern port systems amidst port digitalization and global logistics connectivity (Bueger & Liebetrau, 2023). Beckman (2013), in his study of the UN Convention on the Law of the Sea and South China Sea disputes, emphasized that the complexity of contemporary maritime threats compels coastal states to strengthen maritime legal instruments, deepen cross-border cooperation, and prioritize multilateral governance to ensure the sustainable protection of marine resources in this era of global openness.

The Indonesian government still faces major challenges due to persistent development imbalances between the western and eastern regions. Eastern Indonesia holds enormous potential in the form of abundant fisheries, seabed mineral resources, and significant marine energy reserves. However, supporting infrastructure such as modern shipyards, adequate naval bases, and advanced marine research centers has not yet developed optimally to harness this potential (Silalahi et al., 2021). Laksmana (2020) emphasized the need for the government to shift maritime defense policy focus beyond Java to achieve a balanced national maritime power. Thus, strengthening the maritime sector in the eastern region must involve strategic infrastructure development, human resource capacity building, and sustainable technological innovation.

Globally, the urgency to protect undersea infrastructure is increasing, especially due to the rising cases of sabotage targeting subsea communication cables. McCabe & Flynn (2024) noted that the sabotage of the Nord Stream pipeline in Europe in 2022 served as a stark reminder of the vulnerability of vital undersea infrastructure that supports communication systems and energy distribution. Zhang et al. (2022) stressed the need for an integrated Maritime Data Security Management Platform to ensure effective cross-agency monitoring and protection of subsea assets. This aligns with Kraska's (2011) perspective in Maritime Power and the Law of the Sea, which emphasizes that safeguarding undersea communication lines should be a top priority in modern maritime defense policies, as subsea vulnerabilities can greatly affect national stability and geopolitical relations.

Lessons from the management of the Maritime Silk Road provide valuable insights for Indonesia, especially in formulating strategies to strengthen maritime supply chains in response to global dynamics. Jiang et al. (2023) highlighted that potential supply chain risks must be anticipated through collaborative approaches involving multiple actors and layered risk management to maintain secure logistics flows. In this context, Etzkowitz & Leydesdorff's (2000) Triple Helix concept underscores the need for synergy among government, academia, and industry to drive continuous innovation. Such collaborative approaches are highly relevant for Indonesia, which, as an archipelagic nation, relies heavily on local ports and integrated maritime distribution routes (Ringsberg & Cole, 2020). Therefore, cross-actor coordination is key to maintaining the stability of the national maritime supply chain.

Experiences in various countries show that cooperation models involving only the three main actors-government, industry, and academia-are often insufficient to address the multidimensional challenges faced by Indonesia's maritime sector. Recognizing this complexity, the Hexa-Helix concept emerged, expanding the network of stakeholders by including the military as a sovereignty guardian, coastal communities as monitors and empowerment partners, and mass media as channels for social control and policy transparency. Beseng & Malcolm (2021), through a study in the Gulf of Guinea, emphasized

that active local community involvement plays a crucial role in curbing IUU Fishing that harms coastal states. This proves that grassroots community participation is essential. Similarly, Doddema et al. (2020) stressed the importance of traceability in marine catch commodities to ensure that fisheries protection efforts are effective and produce tangible impacts on marine resource governance in practice.

Eastern Indonesia's vast coastal stretches and rich marine resources often attract illegal fishing practices or IUU Fishing. This situation is worsened by weak maritime patrol systems and suboptimal coordination among law enforcement agencies on the ground (Beseng & Malcolm, 2021). These surveillance gaps are exploited by foreign vessels and illegal fishers to overharvest marine resources without permission, threatening the sustainability of local fishery ecosystems. Learning from other countries' experiences, it is clear that strengthening maritime security cannot rely solely on formal enforcement. Genuine support from local coastal communities is a determining factor in successful maritime surveillance. This aligns with Bueger's (2015) concept in What is Maritime Security? which asserts that modern maritime security paradigms must prioritize a human security approach. This means empowering coastal communities as active guardians of both surveillance and ecosystem preservation to ensure that Indonesia's maritime sovereignty protection is participatory, sustainable, and impactful at the grassroots level.

Beyond physical protection of ships and maritime infrastructure, data security is becoming increasingly critical amid rapid digital transformation in ports and global logistics chains. Zhang et al. (2022) cautioned that leaks of vessel navigation data or sensitive supply chain information could be exploited for maritime espionage, jeopardizing national strategic interests. Bueger & Liebetrau (2023) similarly highlighted that cyberattacks targeting European ports proved the urgent need for integrated data protection policies aligned with national cyber defense systems. This experience shows that maritime digitalization cannot proceed alone without robust cybersecurity reinforcement. This supports Beckman's (2013) view that in the modern era, maritime domain awareness cannot rely solely on physical patrols but must emphasize rapid information exchange, synchronized inter-agency data sharing, and swift responses to make maritime surveillance more effective, responsive, and adaptive to evolving digital security threats.

Policy formulation in Indonesia's maritime defense sector is still often marked by elitist approaches, potentially hindering the creation of truly inclusive policies that provide broad participation opportunities for directly affected communities. Okafor-Yarwood & Onuoha (2023) observed that in Africa, maritime security policies often operate through top-down models and depend on donor countries' interests, leaving local communities as mere recipients of policies without genuine involvement in decision-making processes. This serves as a reflection for Indonesia, especially in the east, where coastal communities have strong socio-cultural diversity. Policies relying solely on top-down control without empowering local actors risk triggering resistance and reducing implementation effectiveness on the ground. Laksmana (2020) also emphasized that Indonesia's maritime defense strategy should ideally combine military strength (hard power) with the empowerment of coastal community capacity (soft power). This combination is believed to make policies more adaptive, rooted in local wisdom, and relevant to the socio-cultural conditions of border coastal communities who play a vital role in safeguarding maritime sovereignty.

These complex challenges demonstrate that strategies to strengthen the maritime defense industry in Eastern Indonesia can no longer depend on isolated sectoral policies. A cross-sector approach that is practically connected on the ground is needed to manage all potentials and risks in an integrated manner. Within this framework, the Hexa-Helix Collaboration Model emerges as an innovative strategy to address policy fragmentation that often separates the roles of key actors. This approach not only promotes self-reliance in the national shipyard supply chain but also strengthens Indonesia's maritime diplomacy, particularly along strategic Indo-Pacific routes. Furthermore, this model is believed to reduce vulnerabilities such as IUU Fishing and the risks of sabotage to critical undersea infrastructure. Anchored in the Triple Helix theory (Etzkowitz & Leydesdorff, 2000), risk

management lessons from the Maritime Silk Road (Jiang et al., 2023), and best practices in subsea protection in Europe (McCabe & Flynn, 2024), this research aims to support Indonesia's vision of becoming a Global Maritime Fulcrum while solidifying the eastern region as the front line of the national maritime defense system.

2. Methods

This study adopts a qualitative descriptive approach supported by literature review and strategic policy analysis. Data were primarily collected from recent peer-reviewed journals, government reports, and relevant legal frameworks related to maritime security, geospatial infrastructure, and the Hexa-Helix collaboration model (Fig.1). The research focused on the Eastern Indonesian maritime zone as a case study area, combining secondary data on regional maritime industry development, digital transformation, and subsea infrastructure protection. To strengthen the analysis, thematic coding was applied to extract key patterns regarding the roles of six stakeholder groups: government, military, academia, industry, media, and coastal communities. This was complemented by comparative policy analysis referencing best practices from international maritime security and subsea infrastructure governance. In addition, SWOT analysis was used to map strategic opportunities and challenges in implementing the Hexa-Helix model. Cross-validation was carried out by triangulating findings from different sources to ensure consistency and reliability. The overall method emphasizes practical insights that connect conceptual frameworks with real-world maritime governance issues, aligning with Indonesia's vision to become a resilient maritime fulcrum in the Indo-Pacific region.

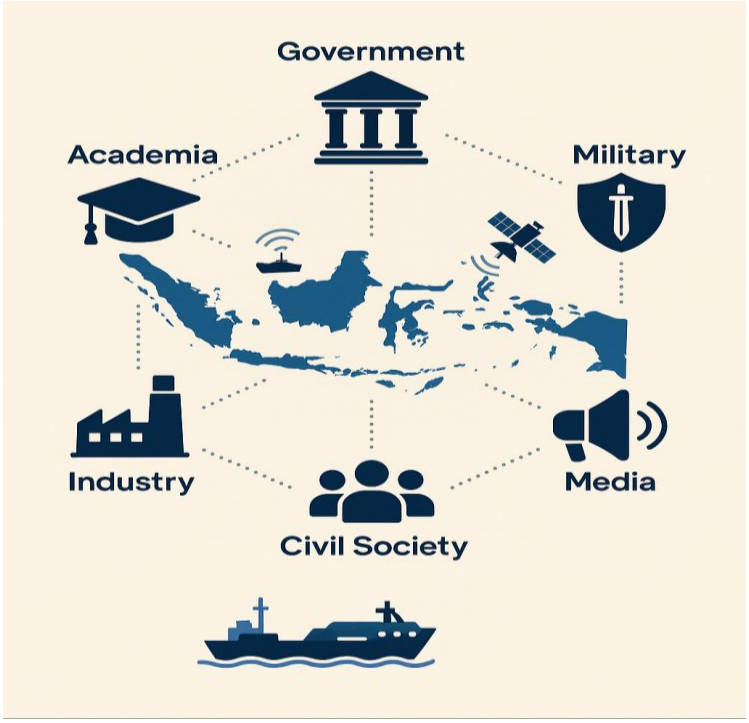

Fig. 1. Hexa helic collaboration model

3. Results and Discussion

3.1 Digital transformation, cyber risk, and smart ports

The digital transformation within Indonesia's maritime sector, especially in its eastern region, can no longer be seen merely as an attempt to follow global trends, but rather as a fundamental prerequisite to strengthen national logistics networks, enhance port

operational efficiency, and minimize vulnerabilities to cybercrime (Fig.2). Numerous studies have confirmed that port operational digitalization directly contributes to significantly reducing logistics costs. It also speeds up ship loading and unloading times, which have long been a source of congestion at sea distribution routes due to lengthy docking queues and rising docking fees (Bolbot et al., 2022). Unfortunately, the implementation of Smart Ports in Indonesia still reveals a stark disparity between the western and eastern regions. Major ports in the west, such as Tanjung Priok in Jakarta, Batu Ampar Port in Batam, and Belawan in North Sumatra, have started adopting Internet of Things (IoT) sensors, automated cargo tracking systems, and digital command centers. However, in the eastern part of the archipelago, such infrastructure support remains unevenly distributed (Silalahi et al., 2021). In fact, ports in eastern Indonesia hold great strategic potential as they are located along ALKI II and III, which are vital routes connecting the Pacific and Indian Oceans.

As Bolbot et al. (2022) explained, the Smart Port concept is not just about building port systems equipped with advanced technologies. More than that, a Smart Port is an integrated ecosystem that combines IoT to monitor real-time cargo movement, utilizes Big Data to analyze loading and unloading patterns, and adjusts ship schedules for greater efficiency. With an integrated system, port operators can make data-driven decisions, minimize cargo pile-ups at docks, and reduce illegal levies that frequently occur at conventional ports. However, technological advances in ports also create new vulnerabilities. Park et al. (2023) warned that the increasingly complex and interconnected digital port systems within a network-centric system open opportunities for cyberattacks that threaten the smooth flow of cross-border logistics. A real example occurred at the Port of Antwerp, Belgium, which was once paralyzed by a ransomware attack that penetrated its port management system. This incident proved that a single weakness in the port management system could disrupt the international logistics supply chain and result in significant economic losses.

In the shipbuilding sector, the trend of digitalization is equally crucial. Razmjooei et al. (2023) highlighted the importance of implementing Digital Twin technology and predictive sensors to detect ship damage early, plan routine maintenance, and speed up fleet retrofitting processes. This technology can extend ships' operational lifespans and reduce sudden repair costs. However, in reality, shipyards in Maluku, Papua, and East Nusa Tenggara still rely on traditional work methods with low levels of automation. One of the main obstacles is the lack of a skilled workforce capable of operating digital systems and the unequal availability of internet infrastructure to support digitalization activities in shipyard areas. Navigation safety also greatly benefits from AI-based technology. Research by Ksciuk et al. (2023) and Rawson & Brito (2023) showed that using Machine Learning can analyze historical data such as extreme weather patterns, ocean currents, and previous ship routes. With this machine learning system, the potential for maritime collisions can be anticipated earlier through route simulations and automatic navigation adjustments. This is highly relevant for the eastern Indonesian waters, which are known for sudden weather changes, strong winds, and high waves.

In the subsea context, Ngo et al. (2023) demonstrated through the Deep Variational Information Bottleneck that object detection accuracy in the ocean can be increased even with limited data. This technology supports early warning systems for undersea cable routes. McCabe & Flynn (2024) emphasized that the data cables crossing ALKI not only support civilian interests like global internet communication but also serve national defense command lines. The sabotage of the Nord Stream gas pipeline in Europe is a stark reminder that subsea vulnerabilities can become targets of sabotage with transnational economic and diplomatic repercussions. Acknowledging the critical role of subsea assets, Zhang et al. (2022) advocated for developing an integrated Maritime Data Security Management Platform to enable cross-agency subsea monitoring and security—spanning the Navy, Bakamla, Ministry of Transportation, and private port operators. Such a data management system can minimize overlapping jurisdictions, accelerate information exchange between institutions, and support rapid response processes when anomalies are detected undersea. Unfortunately, to date, Indonesia still lacks a truly integrated national maritime data hub.

On the other hand, serious challenges also arise regarding the potential marginalization of human labor due to port automation and autonomous shipping operations. Shahbakhsh et al. (2021) and Galani (2020) warned that the automation revolution, if not accompanied by labor protection policies, could reduce maritime job opportunities and widen income disparities in coastal areas. Therefore, digital transformation must be followed by reskilling programs for port workers, cybersecurity training for ship crews, and drafting SOPs to mitigate hacking incidents at ports and shipping lanes (Akpan et al., 2022). In conclusion, the digital transformation of eastern Indonesia's maritime sector is not optional but necessary to catch up with logistics infrastructure development, enhance supply chain competitiveness, and strengthen maritime sovereignty along strategic Indo-Pacific routes. However, all technological innovations must go hand in hand with improving workforce competence, ensuring social protection, and reinforcing cybersecurity regulations so Indonesia is truly prepared for the era of advanced smart maritime logistics.

Fig. 2. Digital transformation, cyber risk and smart ports

3.2 Port connectivity, resilience, and the blue economy

Enhancing port connectivity quality is a vital barometer to measure how robust a nation's logistics resilience system is, especially amid the increasingly complex global supply chains that connect continents. According to Bouazza et al. (2023), ports integrated into international trade routes have a significant impact on boosting a country's export capacity. Moreover, such integration supports the reduction of carbon footprints through efficient route management, thus minimizing energy waste and curbing greenhouse gas emissions that are harmful to the environment. In the context of Indonesia, especially its eastern regions, port connectivity faces dual challenges. Ilyas et al. (2023) explained how the COVID-19 pandemic served as a real test of how crucial ports are in maintaining logistics supply stability. When Southeast Asian ports had to restrict operational hours, cut workforce numbers, or even close services temporarily due to public health policies, container congestion at docks ensued. This not only caused delays in global goods distribution but also triggered a shortage of empty containers, which inflated global logistics costs. In eastern Indonesia, this situation was exacerbated by the dominance of feeder ports that generally only serve ships with limited cargo capacities, despite the region's strategic position as a hub for ALKI II and III international sea lanes connecting the Pacific and Indian Oceans through the Indonesian archipelago (Fig.3.).

To tackle this challenge, modernizing ports in the eastern region can no longer be postponed. The concept of modern feeder ports should not only focus on building physical docks but also equipping every port hub with the latest digital technologies. Turedi & Ozer-Caylan (2021) stressed the need to implement digital gates linked to real-time container tracking systems. With such digital tracking, the flow of incoming and outgoing goods can be always monitored, minimizing loss risks and shortening loading and unloading times.

Modern ports are also required to have export-standard cold storage facilities to ensure that easily perishable marine products such as tuna, lobsters, and seaweed maintain their quality until they reach destination markets. Such cold chain facilities will protect fishermen from potential losses due to spoilage during peak fishing seasons. Thus, the export value of fishery products from eastern Indonesia can increase significantly by meeting international market standards.

Fig. 3. Port connectivity, resilience, blue economy

However, physical development alone is insufficient without cross-sectoral policies that are interconnected and well-synchronized. Sunyowati et al. (2023) emphasized that regulatory harmonization is essential to avoid overlapping authorities between port administrations, maritime law enforcement, and local governments. Without proper coordination, bureaucratic friction on the ground can hinder smooth logistics distribution. In supply chain architecture, the hub-and-spoke approach is believed to be one of the most relevant strategies for eastern Indonesia. This model divides ports into two types: main hub ports handling large-scale cargo loading and unloading, and secondary spoke ports distributing goods to surrounding small islands. With this system, logistic vessels no longer need to repeatedly return to the main port but can simply deliver goods to nearby spoke ports closer to final destinations. This system has proven to save fuel costs, reduce travel time, and extend distribution reach to the outermost islands.

Another important aspect to remember is that port connectivity not only supports civilian trade activities but also functions as infrastructure for national defense. Amelia et al. (2022) highlighted that a secure logistics route strengthens the operational capability of Indonesian Navy/*Tentara Nasional Indonesia Angkatan Laut* (TNI AL) bases in border regions. Naval bases located far from the main distribution centers in Java will heavily rely on nearby ports to ensure the supply of fuel, food, ammunition, and other logistical needs. Without an efficient distribution system, the combat readiness of naval fleets could be compromised, creating openings for foreign infiltration in vulnerable areas. Beyond serving as logistics nodes and military supply chains, ports in the eastern region also hold vast potential to be optimized as centers for the Blue Economy. Under this framework, ports do not function merely as transit terminals but also as value-added hubs that increase regional income. One example is the development of integrated marine product processing areas near ports. With ice factories, packaging facilities, and cold warehouses directly connected to the docks, local fishermen no longer need to sell raw catches at relatively low prices. Processed products such as frozen fish, tuna fillets, or ready-to-export shrimp have significantly higher selling prices in international markets.

To promote a sustainable Blue Economy, Amelia et al. (2022) recommended that the government provide fiscal incentives supporting investments in green shipping. The development of eco-friendly cargo vessels, efficient fuel use, and the implementation of emission reduction technologies in ports must be prioritized within the central and regional government's fiscal policy frameworks. In this way, ports in eastern Indonesia will not only

serve as regional economic nodes but also engines for green policy implementation aligned with Indo-Pacific sustainability agendas. Thus, strengthening port connectivity in the eastern region not only addresses logistical challenges but also supports Indonesia's vision as a resilient Maritime Fulcrum capable of adapting to the dynamics of global supply chains. The key is to develop modern ports that integrate physical infrastructure, digital technology, cross-sectoral coordination, and the empowerment of coastal communities to ensure the maritime economic chain runs sustainably. Without such strategic measures, the vast potential of the eastern region will remain a narrative on paper without tangible impacts on the welfare of coastal communities and national logistics independence.

3.3 IUU fishing threats, fishery crime, and social resilience

The issue of Illegal, Unreported, and Unregulated (IUU) Fishing remains one of the persistent challenges burdening the management of Indonesia's waters, especially in eastern regions renowned for their abundant marine resources. Areas such as Maluku, Papua, and the Arafura Sea hold significant fishery potential but ironically continue to struggle under weak surveillance systems. Beseng & Malcolm (2021), in their study of the Gulf of Guinea, clearly illustrated how fragile coastal governance in West African nations has opened the door for coordinated transnational IUU Fishing practices. This finding simultaneously proves that the greater the marine resource reserves of an area, the greater its appeal to foreign fishing vessels exploiting lapses in national maritime patrols.

Indonesia's eastern waters display a similar pattern. Their vast maritime areas, complex sea topography, and limited patrol fleets and personnel make the region an easy target for foreign fishing vessels operating illegally. The Arafura Sea, for example, has long been known as one of the nation's main fishery hubs but is also notorious as a route for foreign fishing vessels harvesting marine resources without official permits. McCabe (2023) emphasized that excessive fishing not only threatens ecological balance and reduces the waters' regenerative capacity but also fuels social tensions among local fishing communities. When catches decline, the potential for conflicts between local fishing groups increases, not to mention the risk of clashes with patrol forces or possible diplomatic conflicts due to violations of the Exclusive Economic Zone (EEZ).

One of the root causes of the IUU Fishing problem lies in the still low level of maritime legal literacy among traditional fishermen. Song (2023) noted that Indonesian fishermen's EEZ boundary violations often occur not intentionally but due to limited navigation technology and basic knowledge of maritime boundary rules. In practice, many small-scale fishers rely on inherited traditional knowledge that often does not align with modern maritime boundary maps. This gap is further worsened as law enforcement still leans heavily on repressive measures raids, vessel seizures, and arrests without adequate legal education programs for coastal villages where traditional fishing activities originate. Lu & Yamazaki (2023), through their study in East Asia, demonstrated how competition for marine resource access could trigger social unrest in coastal areas if not handled through empowerment approaches. This finding serves as an important lesson for Indonesia: addressing IUU Fishing requires not only strengthening patrol fleets but also tackling the root cause by expanding legal literacy and providing simple, accessible navigation technology for small-scale fishers.

In terms of social protection for maritime workers, Karakasnaki et al. (2023) and Shahbakhsh et al. (2021) underlined the poor working conditions faced by traditional crews in many Indonesian coastal regions, which still fall far short of decent labor standards. Many work without health insurance, job protection, or adequate legal safeguards. Such social vulnerability makes traditional fishers and ship crews prone to debt bondage, forced labor, and involvement in transnational human trafficking networks. In this context, Galani (2020) stressed that the principle of human rights at sea must form the foundation of modern maritime policies. Marine ecosystem protection must go hand in hand with guarantees for the well-being of those who rely on it, so conservation policies do not adversely affect the livelihoods of fishing communities.

Furthermore, to reduce complete dependence on marine catches, Zamzami & Effendi (2023) emphasized the importance of nurturing an entrepreneurial culture in coastal villages. Communities that rely entirely on fishing income are highly vulnerable when fishing seasons are unpredictable or when seasonal fishing bans are enforced. In such conditions, fishers and their families often have no alternative income sources. Therefore, economic diversification is imperative. Seafood processing businesses, sustainable aquaculture, and conservation-based marine tourism are proven diversification strategies that can generate added economic value without putting excessive pressure on marine ecosystems. This approach also opens up new employment opportunities in coastal villages, reduces forced urban migration, and safeguards the livelihoods of communities on the front lines of Indonesia's territorial waters.

In short, addressing IUU Fishing in Indonesia, particularly in its eastern regions, will only be effective if it involves an integrated, cross-aspect approach. Maritime surveillance must be enhanced with adequate patrol fleets and detection technologies. However, law enforcement must also be complemented by grassroots maritime legal literacy and strengthened social protection policies for traditional fishers. Equally important, coastal economic diversification strategies must be encouraged to ensure social and ecological resilience. By doing so, a human security approach and good ocean governance can serve as the foundation for protecting national waters adaptively, equitably, and sustainably amid ever-evolving global challenges (Fig.4).

Fig.4. IUU fishing threats, fishery crime, and social resilience

3.4 Indo-pacific region, diplomacy, and regional security

In the past decade, the geopolitical dynamics in the Indo-Pacific region have grown increasingly complex. Indonesia's strategic Archipelagic Sea Lanes/*Alur Laut Kepulauan Indonesia* (ALKI) are no longer merely traversed by merchant vessels but have also become thoroughfares for military fleets from major powers competing to secure energy and international trade distribution routes (Li et al., 2023). To address these overlapping interests, the ASEAN Outlook on the Indo-Pacific (AOIP) was established as a regional cooperation framework to maintain a balance between economic and security interests in Southeast Asia (Yildiz, 2023). However, Okafor-Yarwood & Onuoha (2023) noted that

maritime policy implementation is often hampered by elitist and bureaucratic approaches that fail to adequately accommodate grassroots public participation.

Experiences from other regions offer valuable lessons. Ávila-Zúñiga Nordfjeld & Dalaklis (2021) highlighted how weak ocean governance in the Gulf of Mexico has led to a resurgence of modern piracy, even under the shadow of nations with strong military capabilities. This demonstrates that relying solely on military power is insufficient without adaptive ocean governance. Meanwhile, Nikolic et al. (2023) stressed the importance of High-Frequency Surface Wave Radar (HFSWR) to detect potential illegal activities, sabotage, or espionage in offshore zones, especially in energy exploration areas prone to conflicts of interest.

In Indonesia's context, the effectiveness of Navy bases in the eastern border regions cannot be maximized if they are disconnected from civilian logistics networks that support the supply of fuel, ammunition, and other necessities for naval crews. Amelia et al. (2022) emphasized the critical importance of integrating military infrastructure with commercial ports to ensure safe supply routes, secure energy supplies, and smooth inter-agency communication. Technical diplomacy is also an essential instrument—from joint patrols with neighboring countries and intelligence data exchanges within the EEZ to harmonizing cross-border maritime legal frameworks so that Indonesia is acknowledged globally as a middle power capable of maintaining the neutrality of its strategically vital ALKI routes.

Nguyen et al. (2023) also pointed out that tackling potential maritime sector disruptions cannot rely solely on routine policy approaches. They emphasized the need for evidence-based policies built on in-depth, systematic literature studies. To achieve this, the Hexa-Helix model offers a concrete solution: academics supply research, the military safeguards sovereignty, coastal communities act as observers, industry drives production, and mass media ensures policy transparency. This multi-stakeholder synergy is expected to strengthen Indonesia's position in maintaining the stability of Indo-Pacific sea lanes while building inclusive and resilient national maritime security amid dynamic geopolitical rivalries (Fig.5).

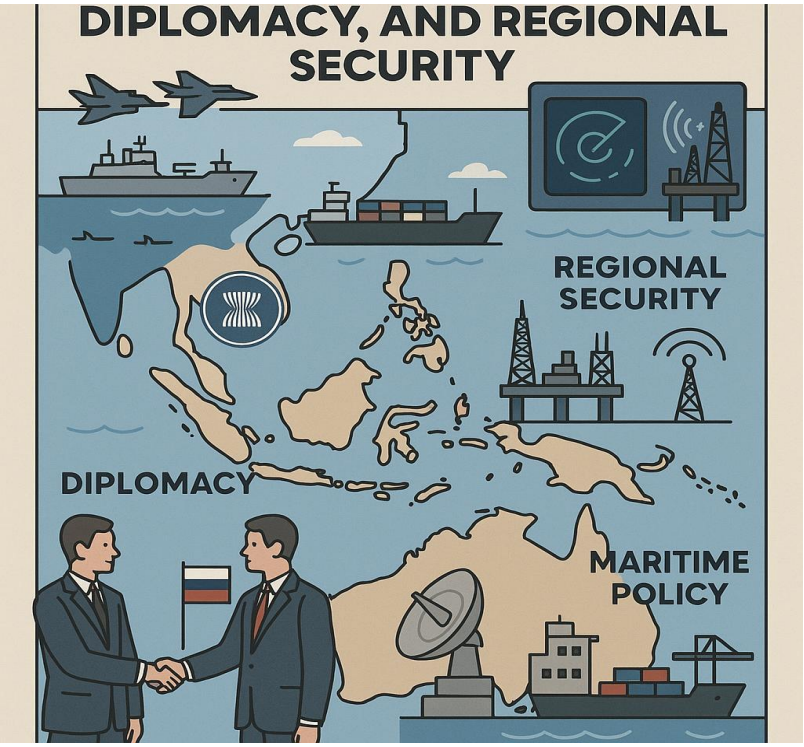

Fig. 5. Diplomacy and Regional Security

3.5 Hexa-Helix action roadmap

The various dynamics and increasingly complex challenges in Indonesia's maritime sector clearly show that the Triple Helix approach focused on synergy among government, industry, and academia is no longer sufficient to tackle the modern maritime era's multifaceted issues. Zhang et al. (2022) and Ngo, Lee, & Kim (2023) highlighted the importance of Indonesia having an integrated maritime Data Hub to consolidate strategic information from multiple agencies. The presence of such a national data center is critical to support real-time vessel monitoring, strengthen detection of Illegal, Unreported, and Unregulated (IUU) Fishing activities that often evade traditional surveillance, and enable intensive monitoring of subsea infrastructure that is vulnerable to sabotage or cross-border espionage.

In addition to strengthening the maritime data foundation, transforming the national shipbuilding industry is another pressing agenda that must be realized. Razmjooei et al. (2023) urged the government to immediately develop an industrialization roadmap for shipyards using digital twin and predictive maintenance systems. By implementing these predictive technologies, ship maintenance can be carried out more accurately, operational lifespans extended, and emergency repair costs minimized. If optimized, this strategy will enable shipyards in eastern Indonesia to grow as independent production centers, no longer fully reliant on major shipyards in Java that have long dominated the national fleet supply chain.

Modernizing shipyards will not only boost the maritime industry's competitiveness but also ensure continuous fleet readiness, safeguard ALKI routes, and strengthen Indonesia's maritime sovereignty in the strategic Indo-Pacific region. This adaptive technology concept also proves that cross-sector collaboration must extend beyond the Triple Helix so that maritime solutions are formulated innovatively, measurably, and with tangible on-the-ground impact.

In the context of subsea infrastructure protection, McCabe & Flynn (2024) emphasized that securing undersea communication cables and energy pipelines can no longer rely solely on conventional maritime patrols with their limited reach and monitoring frequency. The subsea environment's vulnerable, concealed nature, spanning hundreds to thousands of kilometers, means that physical protection alone is insufficient. Therefore, advanced technologies such as seismic sensors, underwater drones known as Remotely Operated Vehicles (ROVs), and satellite-supported remote sensing must be optimized. These detection instruments can serve as early warning systems when suspicious subsea activities occur, whether sabotage, theft, or natural damage. Such mitigation is vital, given that sabotage incidents like the Nord Stream pipeline attack in Europe have shown that attacks on subsea infrastructure not only cause substantial economic losses but can also provoke political tensions among affected nations.

Moreover, strengthening subsea protection must go hand in hand with empowering coastal communities as frontline guardians of marine spaces. Zamzami & Effendi (2023) emphasized the importance of improving maritime legal literacy among coastal communities so they are more aware of their roles as informal sea monitors. This legal literacy must be accompanied by local economic strengthening. When fishers or coastal communities rely solely on fishing, the risk of overexploiting marine ecosystems rises. Therefore, cultivating coastal entrepreneurship should be a long-term strategy. Income diversification programs through seafood processing businesses, environmentally friendly aquaculture, and marine ecotourism initiatives are practical examples of how communities can have alternative income sources beyond traditional fishing activities. This approach not only supports the economic sustainability of fisher households but also fosters community awareness to help protect marine ecosystems and subsea infrastructure in their regions.

Beyond technical protection and local community empowerment, the role of mass media must not be overlooked. Amelia et al. (2022) reminded us that maritime transformation, including subsea protection modernization, must be accompanied by strong, independent oversight mechanisms. Here, the media plays a strategic role as the public's watchdog. The media ensures that various government policies and programs are not merely on paper but are genuinely implemented on the ground as intended. Mass media

also serves as a channel for the aspirations of coastal communities whose voices often go unheard in national policy forums. Through its social control function, the media can drive accountability, open constructive public discussion spaces, and reduce the potential for budget misappropriation or abuse of authority in subsea protection projects and other maritime infrastructure developments.

Indonesia's success in strengthening subsea protection amid Indo-Pacific geopolitical rivalries does not depend solely on sophisticated detection technologies but also requires tangible support from social elements and active public oversight. A weak physical monitoring system without adequate technological support will create serious security risks for undersea cables and energy pipelines. Conversely, even with advanced subsea technology, efforts will have a limited lifespan if not accompanied by empowering coastal communities to guard, monitor, and detect suspicious activities in their environment. Mass media plays a vital role as an information bridge, public education channel, and independent monitor of subsea protection policy implementation on the ground. Without the media's role in ensuring transparency, subsea transformation risks stalling at the elite policy level without addressing the real grassroots problems in coastal communities.

This is where the essence of the Hexa-Helix approach is validated. The model emphasizes the importance of real collaboration between academic research and practical needs in the field, from military sectors, port operations, shipyard management, to the development of self-reliant coastal economic ecosystems. Local and central governments must provide fiscal incentives, strengthen cross-sector regulations, and establish joint frameworks among ministries so that subsea transformation and port digitalization progress in tandem. With this multi-actor collaboration, the foundation of national maritime self-reliance will be more robust to face the future strategic challenges and opportunities of the Indo-Pacific region.

4. Conclusions

In conclusion, the Hexa-Helix Collaboration Model is not merely a theoretical academic concept, but a practical framework designed to address real challenges in eastern Indonesia. By integrating six key actors government as strategic policy-maker, the Navy as maritime security guardian, academics as producers of innovative research, the shipbuilding industry as the engine for ship production and fleet maintenance, coastal communities as resource monitors and ecosystem stewards, and media as an information channel and public oversight mechanism this model builds a more resilient, transparent, and sustainable maritime defense ecosystem.

So far, weak inter-agency coordination and sectoral egos have often been major obstacles in developing the maritime sector, especially in geographically remote and conflict-prone areas such as eastern Indonesia. Through the Hexa-Helix approach, this synergy is expected to close bureaucratic gaps, unify fiscal policies, strengthen shipyard production capacity, and drive the adoption of cutting-edge technologies. The development of Smart Ports, the application of Digital Twin systems in shipyards, and the use of Deep Learning for ship detection and subsea monitoring form the foundation of a digital transformation that responds to the challenges of the maritime industry 4.0 era. The success of this collaboration depends on a commitment to building an integrated cross-actor governance system based on the concept of network governance. Every party must have a role, equal participation space, and a transparent accountability system. The central government must prepare fiscal policies and incentives for green technology investment in the shipbuilding industry. Meanwhile, the Navy must continue strengthening naval bases at the borders with modern fleet maintenance and logistics facilities so that the eastern region no longer depends on the maritime industry centers in the west, thus achieving maritime defense self-reliance.

The transformation and strengthening of the maritime defense industry in eastern Indonesia must also be understood within the broader geopolitical context of the Indo-

Pacific region. As an archipelagic state strategically positioned along ALKI routes, Indonesia must ensure that its maritime policy direction remains aligned with the ASEAN Outlook on the Indo-Pacific (AOIP) framework. This policy alignment is vital so that regional maritime cooperation runs in balance and continues to prioritize Indonesia's national interests amid shifting geopolitical dynamics. This strategy includes efforts to strengthen defense diplomacy with partner countries, build and secure a safe and sustainable maritime logistics supply chain, and protect undersea communication cable routes from sabotage threats that could disrupt national security stability. Therefore, maritime defense industry transformation does not stand alone but is closely linked to the Indo-Pacific regional cooperation agenda.

Beyond structural factors, empowering fishers and coastal communities remains a vital pillar. They are not only marine resource users but also the frontline monitors of IUU Fishing and players in sustainable fishery export value chains. Strengthening digital literacy, maritime legal education, and local community engagement is necessary so that the transformation of the maritime defense industry does not only focus on infrastructure but also touches on social dimensions. Thus, Indonesia's aspiration to become a Global Maritime Fulcrum will no longer be just a slogan. Through the Hexa-Helix Collaboration Model, eastern Indonesia can grow into an independent, modern, and adaptive maritime defense industrial hub while serving as a strategic bulwark against the increasingly competitive Indo-Pacific dynamics. Moving forward, the commitment of all parties to building an innovation-driven, literacy-based, and sustainable maritime ecosystem will serve as a solid foundation for the sovereignty of the Indonesian seas.

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