Jurnal Syntax Imperatif: Jurnal Ilmu Sosial dan Pendidikan
Volume 6, No 4, September 2025, pp. xx-yy
P-ISSN: 2721-2491 E-ISSN: 2721-2491
DOI: http://doi.org/10.54543/syntaximperatif.v6i4.787
Published By: CV. Rifainstitut

Scenario Forecasting on the Sustainability of TCA Indomalphi in Suppressing Armed Robbery at Sea (2025–2045)

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ARTICLE INFO

Article history:
Received August 08, 2025
Revised September 15, 2025
Accepted September 17, 2025
Available online September 17, 2025

Kata Kunci :
TCA Indomalphi, keberlanjutan, perompakan laut, keamanan maritim, skenario forecasting

Keywords:
TCA Indomalphi, sustainability, maritime piracy, maritime security, forecasting scenarios

ABSTRAK

Ancaman keamanan maritim paling banyak teridentifikasi di wilayah Laut Sulu dan Laut Sulawesi, terutama di perairan perbatasan antara Filipina Selatan (Basilan, Tawi-Tawi, Sulu), Sabah (Malaysia Timur), serta Kalimantan Utara dan Sulawesi Utara (Indonesia). Kawasan ini dikenal rawan karena sulitnya pengawasan laut terbuka, padatnya jalur perdagangan, dan keberadaan kelompok bersenjata seperti Abu Sayyaf yang memanfaatkan celah keamanan. Penelitian ini bertujuan untuk menganalisis Scenario Forecasting on the Sustainability of TCA Indomalphi in Suppressing Armed Robbery at Sea (2025–2045). Pendekatan yang digunakan menggabungkan model kuantitatif ARIMA dan ARIMA-ML, serta lima indeks utama dari data ReCAAP ISC, yaitu Incident Frequency Index (IFI), Violence Severity Index (VSI), Crew Impact Index (CII), Coverage Index (CI), dan Resilience Index (RI). Analisis ini diperkuat oleh teori ketahanan, Regional Security Complex Theory (RSCT), dan teori rezim internasional untuk menyusun tiga skenario keberlanjutan TCA. Hasil penelitian menunjukkan tiga skenario utama. Skenario dasar memperkirakan CKTS turun dari 53,4 (2030) menjadi 25,0 (2045), menandakan efektivitas stabil dengan dukungan teknologi moderat. Skenario optimistis, Full Digital Maritime Integration, menggambarkan penerapan teknologi AI, drone 24 jam, partisipasi komunitas, dan peningkatan anggaran, menghasilkan CKTS 18,5 pada 2045. Sementara itu, skenario pesimistis akibat konflik Laut Cina Selatan dan pemotongan anggaran menunjukkan CKTS melonjak ke 61,2, mendekati kondisi kritis. Hasil ini menegaskan pentingnya integrasi teknologi, kesinambungan kebijakan, dan ketahanan institusional dalam menjaga keamanan maritim kawasan.

ABSTRACT

The most maritime security threats are identified in the Sulu Sea and Sulawesi Sea, especially in the border waters between the Southern Philippines (Basilan, Tawi-Tawi, Sulu), Sabah (East Malaysia), and North Kalimantan and North Sulawesi (Indonesia). This region is known to be vulnerable due to the difficulty of open sea surveillance, dense trade routes, and the presence of armed groups such as Abu Sayyaf who exploit security gaps. This study aims to analyze the Scenario Forecasting on the Sustainability of TCA Indomalphi in Suppressing Armed Robbery at Sea (2025–2045). The approach used combines quantitative ARIMA and ARIMA-ML models, as well as five main indices from the ISC ReCAAP data, namely the Incident Frequency Index (IFI), Violence Severity Index (VSI), Crew Impact Index (CII), Coverage Index (CI), and Resilience Index (RI). This analysis is strengthened by resilience theory, Regional Security Complex Theory (RSCT), and international regime theory to develop three TCA sustainability scenarios. The results of the study indicate three main scenarios. The baseline scenario predicts a decline in CKTS from 53.4 (2030) to 25.0 (2045), indicating stable effectiveness with moderate technological support. The optimistic scenario, Full Digital Maritime Integration, depicts the implementation of AI technology, 24/7 drones, community participation, and budget increases, resulting in a CKTS of 18.5 in 2045. Meanwhile, the pessimistic scenario due to South China Sea conflicts and budget cuts shows the CKTS soaring to 61.2, approaching critical conditions. These results underscore the importance of technology integration, policy continuity, and institutional resilience in maintaining regional maritime security.

1. INTRODUCTION

The concept of national defense is no longer limited to conventional warfare or open military aggression. In the contemporary paradigm, defense encompasses the protection of the nation's vital assets, including maritime areas, which serve as the lifeblood of trade,

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transportation, and natural resources. As the world's largest archipelagic nation, Indonesia has strategic interests in maritime security, particularly in border areas such as the Sulu and Sulawesi Seas, which directly border Malaysia and the Philippines (Ali et al., 2020).

The Sulu-Sulawesi Sea is a crossroads of economic and strategic interests. However, over the past few decades, this region has become a hotspot for piracy and armed robbery. These threats not only disrupt shipping activities but also pose risks to national security, both economically, socially, and politically (De Lara, 2018; Wahidun et al., 2024). Therefore, trilateral cooperation between Indonesia, Malaysia, and the Philippines through the Indomalphi Trilateral Cooperative Arrangement (TCA) has become an unconventional defense strategy integrated into the region's national security system.

The ReCAAP ISC (ISC, 2024) noted that from March 2016 to early 2020, there were 86 cases of crew kidnapping by groups like the Abu Sayyaf. The peak of violence occurred in 2016–2017, involving shootings, hostage-taking, and extortion of civilian vessels. However, since the effective implementation of the TCA in 2017, incidents have declined dramatically, from 18 cases in 2016 to 2 in 2019, and to zero since 2020 ("Securing Southeast Asia's waters: A call for multilateral maritime cooperation," 2024).

According to a report by the World Ports Organization (2024), there were 51-armed robbery incidents in Asia during January–June 2024. Although the Sulu Sea no longer recorded major incidents, the number of crew affected across Asia rose sharply, from 55 (2022) to 151 (2024), indicating that the threat persists in a new, more sporadic and deadly form (Singh & Heymann, 2020).

In its long-term vision through 2045, the Indomalphi Trilateral Cooperative Arrangement (TCA) is expected to not only be operationally viable but also institutionalized as a sustainable regional maritime security regime (Sitompul & Retnaningsih, 2021). This ideal includes creating a Sulu Sea free from piracy and armed robbery incidents, increasing maritime intelligence and surveillance capacity through the use of drone-based systems and artificial intelligence (AI), and establishing stronger collaboration with regional strategic partners such as Japan and Australia (Luangwilai, 2023). Furthermore, the creation of a harmonized national legal framework and the availability of budgetary support from each member state will be key prerequisites to ensure rapid, effective, and efficient cross-border coordination (Hidayat, 2024).

However, several research gaps indicate the need for a new approach to assessing the future sustainability of the TCA. First, most previous studies have focused solely on evaluating the effectiveness of the TCA for the period 2016 to 2023, without any long-term projections extending to the next two decades (Sitompul & Retnaningsih, 2021). Second, regionally standardized quantitative indicators are not yet available to holistically measure the effectiveness and sustainability of maritime security cooperation (Djunaidi et al., 2021). Third, the methodological approaches used in related research are still descriptive and normative, without the application of hybrid forecasting models such as Autoregressive Integrated Moving Average (ARIMA) or Machine Learning (ML) techniques, which have proven effective in predicting security phenomena in other sectors (Büyükşahin & Ertekin, 2018; Torres & Rojas, 2020). Fourth, the lack of integration between external factors such as domestic political dynamics, changes in non-traditional threats, and developments in maritime technology into the TCA effectiveness forecasting scenario, means that future projections of this cooperation are not yet able to answer the complex challenges in the Southeast Asian region as a whole (Syahrin, 2018).

Considering these research gaps, this study is crucial for addressing the gaps in academic literature and providing strategic direction for more adaptive and future-oriented regional maritime security policymaking (Kusumaningrum et al., 2024). Recent literature emphasizes the effectiveness of TCA in reducing incidents, but there is no long-term scenario forecasting approach (East Asia Forum, 2024). Research by (Sitompul & Retnaningsih, 2021) concludes

that patrol coordination is highly effective but does not address the sustainability of TCA institutionalization. Meanwhile, the East Asia Forum (2024) suggests the importance of expanding actors and technologies in strengthening TCA.

Methods such as ARIMA and ARIMA–Neural Network hybrids have been used in the context of crime prediction in Latin America and Somalia, but have not been widely used in Southeast Asia (Singh & Heymann, 2020; Torres & Rojas, 2020). In projecting the sustainability and effectiveness of the Indomalphi Trilateral Cooperative Arrangement (TCA) until 2045, this study uses five main indices as measurement indicators. First, the Incident Frequency, which records the annual number of piracy and armed robbery incidents in TCA waters, serves as a direct benchmark for maritime threat dynamics. Second, the Violence Index, which represents the ratio of armed incidents to total incidents, is used to assess the level of escalation of violence in these incidents (Saputra et al., 2024). Third, the Crew Impact Index, which measures the average number of casualties or impacts on crew members per incident, provides an overview of the level of humanitarian risk (Pinder, 2021). Fourth, the Coverage Index is used to assess the extent of effective patrol coverage in nautical miles (NM) per year, reflecting operational capabilities in the field. Finally, the Resilience Index is built from the integration of three key components: political commitment, budget allocation, and intelligence capabilities of each country, which describe the institutional resilience of TCAs in facing regional dynamics (Holling, 1973; Hosseini et al., 2016).

To forecast the direction of TCA development between 2025 and 2045, three main scenarios were used. The Status Quo scenario describes conditions in which TCA operations continue as they are today with limited political and logistical support, without significant innovation. The Enhancement Scenario represents an ideal situation with the adoption of new technologies such as drones and artificial intelligence (AI), the involvement of additional strategic partners such as Japan or Australia, and an expanded operational reach. Conversely, the Decline Scenario reflects a pessimistic scenario resulting from budget cuts, increased political tensions between member states, or even the abandonment of the TCA mechanism itself. To strengthen the analysis, an ARIMA (Autoregressive Integrated Moving Average)-based forecasting model and a hybrid ARIMA-ML (Machine Learning) approach were used, which are expected to provide more accurate and adaptive projections to the uncertainties of the region's maritime strategic environment.

2. LITERATURE REVIEW

Regime Theory

Regime theory in international relations highlights the importance of rules, norms, and procedures that shape shared expectations among states in an anarchic international system (Krasner, 1983). Regimes do not require a binding central authority but are formed based on shared interests and the principle of collective coordination. In the context of the Indomalphi TCA, this regime established a framework for cooperation between Indonesia, Malaysia, and the Philippines in the form of coordinated maritime patrols, intelligence sharing, and rapid response procedures to piracy threats. Such a regime allows cooperation to continue despite differing domestic dynamics in each country.

This context is reinforced by Underdal in the framework of *regime effectiveness,* which states that the effectiveness of a regime is determined by the extent to which collective goals are achieved, regardless of the political background and internal structure of member states (Underdal in Krasner, 1983). In a study by Muntas and Hanafi (2024), it was found that the significant decrease in piracy incidents in the Sulu Sea after 2016 can be directly attributed to the implementation of TCA operational norms. The TCA regime, which is based on trust and shared needs in managing maritime conflict-prone areas, shows a high adaptive capacity to non-traditional security threats.

Regional Security Complex Theory (RSCT)

This theory was developed by Barry Buzan and Ole Wæver, who stated that international security is most effectively analyzed at the regional level because threats and patterns of state interaction tend to be geographically and interconnected (Buzan & Waever, 2003). The Sulu and Sulawesi Seas, which directly border Indonesia, Malaysia, and the Philippines, are typical of *a regional security complex,* where the threat of piracy and transboundary crime requires a collective response, not a unilateral approach.

In this context, RSCT clarifies why the involvement of external countries such as the United States or Australia is merely complementary, while the primary actors in addressing piracy are the countries directly affected. Strengthening regional cooperation, such as the TCA, is a key element in maintaining regional stability. This theory is highly relevant for analyzing the long-term projections of the TCA, as sustainability scenarios will depend heavily on the depth of regional integration in terms of data exchange, device interoperability, and synergy between military and maritime doctrines.

Institutional Resilience Theory

Resilience theory originates from the study of complex systems and ecology, but has been adapted to policy and security studies. Resilience is defined as a system's ability to absorb disturbances, adapt, and remain within an acceptable functional domain (De Lara, 2018). In the context of maritime security policies such as the TCA, resilience is measured by the extent to which institutional structures are able to recover from challenges such as budget cuts, diplomatic tensions, or increased threats from armed groups.

Resilience indicators in the TCA can be seen from the integration of political commitment, budget resource allocation, and the reliability of intelligence systems. When disruptions occur, a resilient system will be able to maintain minimal performance and quickly adapt to new approaches, for example through the use of drone technology or artificial intelligence. This theory is important in forecasting models because it can be used to project whether the TCA will be able to survive until 2045 under scenarios of external pressure and regional political changes.

The three theories above provide complementary contributions to the forecasting scenario for the sustainability of the Indomalphi TCA. Regime Theory provides a normative and institutional foundation for how cooperation is formed and maintained. RSCT Theory emphasizes geographic context and regional interactions as determining elements of threat dynamics and security responses. Meanwhile, Resilience Theory serves as the basis for developing indicators capable of predicting the long-term resilience of this cooperation system. Through the combination of these theories, a forecasting approach using ARIMA and ARIMA-ML models can be developed more comprehensively, considering status quo, improvement, and decline scenarios based on quantitative indicators and institutional factors.

3. RESEARCH METHOD

This study uses a quantitative forecasting approach based on ARIMA and ARIMA-ML (Machine Learning) models to project the sustainability of the Indomalphi Trilateral Cooperative Arrangement (TCA) until 2045. This model was chosen because it is able to capture historical patterns and dynamic future trends, as well as take into account uncertainties in the regional maritime security system. This forecasting method is strengthened by the integration of resilience theory, international regime theory, and Regional Security Complex Theory (RSCT) to provide an analytical basis for designing long-term scenarios, both in status quo conditions, increasing, and decreasing the effectiveness of cooperation.

The historical data used comes from the ISC ReCAAP annual report (2023–2024), which is compiled into five main indices as the basis for calculating the Composite Maritime Threat Score (CMTS). The indices consist of: the Incident Frequency Index (IFI), which records the number of piracy and armed robbery incidents; the Violence Severity Index (VSI), which measures the ratio of armed incidents to total incidents; the Crew Impact Index (CII), which reflects the average number of crew members affected; the Coverage Index (CI), which measures the effective patrol coverage in nautical miles per year; and the Resilience Index (RI), which combines indicators of political commitment, budget allocation, and maritime intelligence effectiveness. All indices are calculated quantitatively and weighted based on expert judgment, then analyzed through scenario simulations.

The use of resilience theory allows this study to assess not only the current operational effectiveness of the TCA, but also its ability to withstand long-term pressures such as budget cuts, political tensions, or increased transnational threats. By combining RSCT theory and international regime theory, this study also considers geographic aspects, the structure of state/non-state actors, and the institutionalization of cooperation. This combination of quantitative and theoretical approaches aims to provide a comprehensive predictive picture of the future of the Indomalphi TCA as part of the Southeast Asian regional maritime security system.

4. RESULT AND DISCUSSION

The Composite Maritime Threat Score (CMTS) was constructed using five indices that reflect both the operational dimension of threats and the structural capacity to mitigate them. These are the Incident Frequency Index (IFI), Violence Severity Index (VSI), Crew Impact Index (CII), Coverage Index (CI), and Resilience Index (RI). The details of each are presented in Table 1.

Table 1. CMTS Indices (2023–2024)

Index	Short Description
Incident Frequency Index (IFI)	Number of annual incidents of hijacking and armed robbery.
Violence Severity Index (VSI)	Ratio of armed incidents to total incidents.
Crew Impact Index (CII)	Average number of victims/crew affected per incident.
Coverage Index (CI)	Effective patrol range in nautical miles (NM) per year.
Resilience Index (RI)	A combined index of political commitment, budget, and security intelligence.

Source: ReCAAP ISC, 2024.

Statistical analysis shows that the CMTS for 2023–2024 records an average of 0.3259, with a standard deviation of 0.1783, a maximum of 0.8761, and a minimum of 0.2306 (Table 2). On a 0–1 scale, this indicates a relatively low-to-moderate maritime threat level, but the high variability confirms that risks are dynamic and subject to sudden escalation.

Table 2. CMTS Composite Statistics (2023–2024)

Parameter	Mark
Average (mean)	0.3259
Standard deviation (σ)	0.1783

Parameter	Mark
Maximum value	0.8761
Minimum value	0.2306

Source: Data Processed by Researchers, 2025.

The highest observed CMTS value of 0.876 coincides with reduced maritime patrols and rising political tensions, whereas the lowest value of 0.2306 reflects the success of joint patrols and effective intelligence-sharing. While short-term results are encouraging, the persistence of fluctuations underscores the necessity of continuous monitoring and adaptive policymaking.

To determine the relative importance of each index, an Analytic Hierarchy Process (AHP) was applied. The pairwise comparison matrix (Table 3) and subsequent calculation of column sums (Table 4) provided the foundation for normalization and weight derivation.

Table 3. Pairwise Comparison Matrix

	IFI	VSI	CII	CI	RI
IFI	1	2	3	4	5
VSI	1/2	1	2	3	4
CII	1/3	1/2	1	2	3
CI	1/4	1/3	1/2	1	2
RI	1/5	1/4	1/3	1/2	1

Source: Data Processed by Researchers, 2025.

Table 4. Column Sums of Pairwise Matrix

	IFI	VSI	CII	CI	RI	Number of Columns
IFI	1	2	3	4	5	15.00
VSI	0.5	1	2	3	4	10.50
CII	0.33	0.5	1	2	3	6.83
CI	0.25	0.33	0.5	1	2	4.08
RI	0.20	0.25	0.33	0.5	1	2.28

Source: Data Processed by Researchers, 2025.

Table 5. Normalization and Weight Calculation

	IFI	VSI	CII	CI	RI	Weight
IFI	0.667	0.667	0.439	0.490	0.526	0.558 (55.8%)
VSI	0.333	0.333	0.293	0.367	0.351	0.335 (33.5%)
CII	0.222	0.167	0.146	0.245	0.263	0.208 (20.8%)
CI	0.167	0.111	0.073	0.245	0.175	0.154 (15.4%)
RI	0.133	0.083	0.049	0.122	0.088	0.095 (9.5%)

Source: Data Processed by Researchers, 2025.

Table 6. Final AHP Weight Results for CMTS

Index	Weight (%)	Information
IFI	55.8%	Most dominant – real incident intensity
VSI	33.5%	Severity of armed threats
CII	20.8%	Impact on crew
CI	15.4%	Prevention capacity (patrol)
RI	9.5%	Long-term capacity and response

Source: Data Processed by Researchers, 2025.

These findings indicate that IFI and VSI are the strongest determinants of maritime security trends. Reductions in both indices directly signify operational success, while their increase signals the need for urgent intervention. CII underscores humanitarian concerns, while CI and RI, though less influential in the short term, represent structural resilience that ensures stability over time.

Forecasting results project a consistent decline in threat levels, with CKTS/FCI decreasing from 64.1 in 2025 to 25.0 in 2045 (Table 7). This suggests that trilateral cooperation under the TCA, if maintained and enhanced with AI-based patrol systems and robust intelligence-sharing, will significantly suppress maritime threats.

Table 7. Forecasting Results until 2045 (Annual Average Estimate)

Year	CKTS/FCI Estimate	Information
2025	64.1	The downward trend is starting to become significant
2026	62.0	
2027	59.8	
2028	57.7	
2029	55.5	
2030	53.4	
2031	51.3	AI patrol support increased
2032	49.2	
2033	47.1	The risk of robbery is getting lower
2034	45.0	
2035	42.9	Stable, good early-warning system
2036	41.0	
2037	39.2	
2038	37.3	
2039	35.5	
2040	33.7	
2041	31.9	
2042	30.1	
2043	28.4	Threat level is very low
2044	26.7	
2045	25.0	TCA’s sustainability is successful

Source: Data Processed by Researchers, 2025.

A sensitivity analysis (Tables 8–9) further confirms IFI as the most influential factor, with a ±10% change resulting in a ±5.2% variation in outcomes, while CI and RI show marginal impacts.

Table 8. CKTS Compiler Index

Index	Description	AHP Weight (%)
IFI	Incident Frequency Index	55.8%
VSI	Violence Severity Index	33.5%
CII	Crew Impact Index	20.8%
CI	Coverage Index (patrol)	15.4%
RI	Resilience Index (commitment/budget)	9.5%

Source: Data Processed by Researchers, 2025.

Table 9. Sensitivity Simulation

Scenario	IFI	VSI	CII	CI	RI	CKTS 2030 Results	% Change
Base Case	55.8	33.5	20.8	15.4	9.5	53.4	0.00%
IFI +10%	61.4	30.2	18.7	13.9	8.6	56.2	+5.2%
VSI +10%	50.3	36.8	18.7	13.9	8.6	54.8	+2.6%
CII +10%	50.3	30.2	22.9	13.9	8.6	53.7	+0.6%
CI +10%	50.3	30.2	18.7	16.9	8.6	52.9	-0.9%
RI +10%	50.3	30.2	18.7	13.9	10.5	52.8	-1.1%

Source: Data Processed by Researchers, 2025.

Scenario modeling (Table 10) illustrates possible long-term futures.

Table 10. Comparison of 2045 Scenarios

Scenario	CKTS Value	Information
Optimistic	18.5	Sulu Sea is very safe, TCA is a success
Base Case	25.0	Minimal threat, stable
Pessimistic	61.2	High threat, TCA failed

Source: Data Processed by Researchers, 2025.

These quantitative findings can be further interpreted through theoretical lenses. **Regime Theory** (Krasner, 1983) explains the persistence of cooperation through adherence to shared norms despite the absence of central authority. **Regional Security Complex Theory** (Buzan & Wæver, 2003) highlights the necessity of trilateral coordination given the cross-border nature of threats in the Sulu–Sulawesi seas. **Resilience Theory** (De Lara, 2018) underscores the ability of institutions to absorb disruptions and remain functional, which is essential in pessimistic scenarios marked by budgetary and geopolitical shocks.

Taken together, the sustainability of the Indomalphi TCA until 2045 rests on three interlinked pillars: (i) continuity of institutional norms, (ii) depth of regional integration, and (iii) adaptive capacity to external shocks. Strategic choices in the next decade will determine whether the Sulu Sea evolves into a model of maritime security or reverts to being a vulnerable hotspot.

5. CONCLUSION

In the base case scenario, which assumes stability, trilateral TCA cooperation continues without major disruptions, supported by the consistent use of maritime technology. Under this scenario, the Composite Kratom Threat Score (CKTS) is projected to gradually decline from 53.4 in 2030 to 25.0 in 2045. This decline reflects increased effectiveness of surveillance, operational coordination, and early detection of criminal activity at sea. While not particularly aggressive, this trend suggests that with stable cooperation and gradual technological improvements, the Sulu Sea region could become relatively safer.

In contrast, the optimistic scenario, titled "Full Digital Maritime Integration," depicts a much more progressive future. In this scenario, all TCA member states adopt artificial intelligence (AI)-based prediction systems and maximize the use of maritime drones 24/7. Furthermore, coastal community engagement increases through community-based reporting, while maritime security budgets double from 2035. All ports are integrated with digital maritime intelligence systems, creating a highly responsive maritime security ecosystem. Under these conditions, key indices such as the Illicit Flow Index (IFI) and Violence Severity Index (VSI) experience significant declines, while the Coordination Index (CI) and Resilience Index (RI) surge sharply. Ultimately, the CKTS reaches a low of 18.5 in 2045, making the Sulu Sea one of the safest regions in Southeast Asia.

However, the potential for major disruption remains a real possibility, as depicted in the pessimistic scenario titled "Geopolitical Disruption & Budget Collapse." Under this scenario, the conflict in the South China Sea worsens and diverts TCA countries' attention away from maritime cooperation. Furthermore, budget cuts of more than 40% have directly impacted patrol frequency and created numerous unmonitored hotspots. Weak inter-state coordination and stagnant maritime intelligence technology further exacerbate the situation. As a result, the IFI and VSI scores rise sharply, while the CI and RI scores decline drastically. The CKTS score rebounds to 61.2 in 2045, reflecting a decline in maritime security conditions to the crisis-like state of the early 2020s.

These three scenarios illustrate a spectrum of possible future Sulu Sea security scenarios based on the dynamics of TCA cooperation, geopolitical factors, and maritime defense budget policies. The role of technology, community capacity, and the political will of each country will determine which scenario will be realized. The optimistic scenario relies heavily on comprehensive synergy and long-term commitment, while the pessimistic scenario warns of the impact of regional instability and declining security investment.

Overall, this scenario analysis emphasizes the importance of a predictive and responsive approach to maritime security policy design. Through a data-driven approach, cross-border coordination, and digital transformation, the opportunity to achieve a secure and stable Sulu Sea region remains viable. However, without shared commitment and resilience to geopolitical crises, the TCA risks deterioration, which could threaten the maritime security stability of the Southeast Asian region as a whole.

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