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Autonomous Navigation Decision-Making and the Evolving Role of the Officer of the Watch: Implications for MASS Integration in Indonesian Shipping Corridors

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Abstract. *The adoption of Maritime Autonomous Surface Ships (MASS) under the IMO MASS Code represents the most consequential redefinition of the Officer of the Watch (OOW) role in the history of modern seafaring. While autonomous navigation technologies progressively assume operational functions traditionally performed by human officers, the decision-making competencies, supervisory responsibilities, and COLREGs compliance challenges that arise at the human-autonomy interface remain empirically undercharacterized — particularly in the complex, high-traffic, and archipelagic shipping environments of Southeast Asia. This study investigates autonomous navigation decision-making and the evolving OOW role in the context of MASS integration within Indonesian shipping corridors. Employing a qualitative research design, data were generated through semi-structured interviews with senior deck officers, maritime education experts, and maritime regulatory practitioners, supplemented by systematic document analysis of IMO MASS Code provisions and Indonesian domestic shipping regulatory frameworks. Analysis proceeded through thematic analysis, cross-group comparison, and narrative synthesis. Findings reveal that OOW competency frameworks face four structurally unresolved challenges under MASS integration: situational awareness degradation in remote supervisory roles, COLREGs interpretive ambiguity in human-autonomy encounter scenarios, institutional unpreparedness in maritime education curricula, and regulatory gaps in Indonesian domestic MASS governance. The study argues for the urgent development of a MASS-competent OOW framework that integrates autonomous systems literacy, adaptive decision-making training, and regulatory alignment within Indonesian maritime education and policy.*

Keywords: *MASS; autonomous navigation; Officer of the Watch; COLREGs; Indonesian shipping corridors*

1. INTRODUCTION

The history of maritime navigation has been shaped by a succession of technological transformations — from the magnetic compass to the chronometer, from radar to ECDIS — each of which has progressively augmented, and in some respects displaced, the perceptual and analytical capabilities of the human officer on the bridge. Yet none of these prior transitions has approached, in its scope and systemic implications, the transformation now being catalyzed by the emergence of Maritime Autonomous Surface Ships (MASS): vessels capable of operating with reduced or entirely absent human crews, relying on artificial intelligence, machine learning, advanced sensor fusion, and satellite-connected remote supervisory architectures to perform the navigational, collision avoidance, and operational decision-making functions that international maritime law has historically vested in the Officer of the Watch (OOW) (IMO, 2021; Porathe et al., 2014). The IMO's adoption of the MASS Code — formalized at MSC 107 in 2023 and scheduled for entry into force in 2028 — marks the transition of autonomous maritime operation from a speculative technological frontier to an internationally regulated operational reality, establishing a four-tier autonomy classification framework that ranges from vessels with automated decision-support systems (Degree One) to fully autonomous ships without crew on board (Degree Four) (IMO, 2021). This regulatory crystallization does not resolve, but rather sharpens, a set of deeply

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consequential and still largely unresolved questions about the nature, content, and institutional development of the human competencies required to supervise, interact with, and bear legal responsibility for autonomous navigation systems operating in complex and dynamic maritime environments.

The concept of the Officer of the Watch, as codified in the STCW Convention and its Manila Amendments, rests upon a set of assumptions about human presence, perceptual access, and decision-making authority that MASS integration fundamentally complicates (IMO, 2011). Under conventional watch-keeping doctrine, the OOW maintains direct sensory contact with the navigational environment — visually observing traffic, monitoring instrument displays, interpreting weather and sea conditions, and exercising real-time command judgment — within a legal and operational framework premised on the officer's physical presence on the bridge and continuous situational awareness of the vessel's immediate navigational context (Rothblum, 2000). MASS Degree Two and Three operations, by contrast, situate the OOW — reconstituted as a remote operator or supervisory manager — within a shore-based or reduced-crew environment, where navigational awareness is mediated entirely through sensor data streams, camera feeds, AI-generated situation assessments, and digital communication systems (Porathe et al., 2014; Wróbel et al., 2017). The epistemological and competency implications of this shift are profound: the OOW must now exercise judgment not from direct environmental observation but from the interpretation of technologically constructed representations of the navigational situation — representations that carry their own limitations, latencies, failure modes, and interpretive demands that existing OOW training frameworks were neither designed nor equipped to address.

The scholarly literature on autonomous maritime systems has grown substantially since the launch of the Rolls-Royce Blue Ocean project and the subsequent proliferation of MASS research initiatives (Wróbel et al., 2017; Felski & Zwolak, 2020). Research has addressed MASS technical architecture, sensor fusion systems, autonomous collision avoidance algorithms, and the legal implications of autonomous operation under existing maritime conventions — particularly the COLREGs, whose rule-based collision avoidance framework was designed for human officers and contains provisions, such as the obligation to maintain a proper look-out by "sight and hearing" (Rule 5), that are genuinely and unresolvedly ambiguous in their application to autonomous or remotely operated vessels (Burmeister et al., 2014; Rødseth & Burmeister, 2012). Less systematically investigated, however, are the human factors dimensions of MASS integration — specifically, the cognitive, competency, and institutional challenges that arise when human officers are

repositioned from primary navigational decision-makers to supervisors, monitors, or remote operators of autonomous navigation systems. Endsley's (1995) foundational theory of situational awareness — encompassing the perception of environmental elements, their comprehension, and the projection of their future status — provides a theoretically productive lens for examining this repositioning, yet its application to the MASS remote supervisory context remains largely theoretical rather than empirically grounded, particularly in non-Western maritime contexts where the operational, regulatory, and educational environments introduce additional layers of complexity.

Indonesia's maritime context renders the study of MASS integration challenges simultaneously more complex and more urgent than most comparable national settings. As the world's largest archipelagic state — constituted of over 17,000 islands and approximately 95,000 kilometers of coastline — Indonesia operates the world's most extensive domestic shipping network, with vessel traffic distributed across shipping corridors that intersect international straits of global strategic significance, including the Malacca, Sunda, and Lombok Straits (Purwantono et al., 2020). These corridors are characterized by extraordinarily high traffic density, complex interactions between large international vessels and small domestic craft, challenging tidal and meteorological conditions, and the presence of numerous Traffic Separation Schemes (TSS) and archipelagic sea lanes governed by both IMO instruments and Indonesian national regulation under the UNCLOS archipelagic regime (IMO, 2011; Purwantono et al., 2020). The introduction of MASS vessels — whether international carriers transiting Indonesian straits or domestic vessels operating on inter-island routes — into this navigational environment creates collision avoidance and COLREGs compliance challenges of a complexity that has not been adequately characterized in either the MASS research literature or Indonesian maritime policy discourse. The question of how autonomous navigation systems interpret and respond to the give-way and stand-on obligations of COLREGs Rules 13–17 in encounters with conventionally manned vessels in confined, traffic-dense Indonesian corridors is not merely a technical question; it is a safety-critical policy and operational question whose resolution has direct implications for Indonesian maritime governance and for the competency development of Indonesian deck officers who will increasingly find themselves either remotely supervising MASS vessels or navigating conventional ships in proximity to autonomous traffic.

The institutional dimension of this challenge is equally pressing. Indonesia's maritime officer education system — centered on institutions including Sekolah Tinggi Ilmu Pelayaran (STIP) Jakarta and the broader network of maritime polytechnics under the Ministry of

Transportation — currently trains deck officers within a STCW-aligned framework that was developed for conventional, fully crewed vessel operation and that contains no substantive provision for the autonomous systems literacy, remote supervisory competency, or MASS-encounter decision-making skills that MASS integration will progressively demand of Indonesian deck officers in professional practice (IMO, 2011; Wróbel et al., 2017). This institutional gap is not unique to Indonesia — maritime education systems globally have been identified as lagging the pace of MASS development — but it carries particular urgency in the Indonesian context given the volume and strategic importance of shipping operations in Indonesian waters and the national maritime labor export that places Indonesian deck officers in international MASS-integrated vessel environments with increasing frequency (Felski & Zwolak, 2020; Porathe et al., 2014).

Against this convergence of technological, regulatory, operational, and institutional challenges, the present study is organized around a central research question: *How is autonomous navigation decision-making reshaping the role and competency demands of the Officer of the Watch, and what are the specific implications of MASS integration for navigational safety, COLREGs compliance, and maritime officer education in Indonesian shipping corridors?* Three research objectives guide the inquiry: first, to analyze how autonomous navigation systems alter the decision-making architecture and situational awareness demands of the OOW role under MASS Degree One through Three operations; second, to identify the specific COLREGs compliance and collision avoidance challenges that MASS integration generates in the navigational context of Indonesian shipping corridors; and third, to assess the current preparedness of Indonesian maritime education institutions and regulatory frameworks for the competency and governance demands of MASS operation.

The significance of this study operates simultaneously across theoretical, empirical, and practical dimensions. Theoretically, it extends Endsley's situational awareness framework and human factors research into the MASS remote supervisory context, generating a conceptually refined account of OOW competency in autonomous navigation environments. Empirically, it produces the first contextually specific investigation of MASS integration challenges in Indonesian shipping corridors, addressing an absence in both MASS research and Southeast Asian maritime studies literatures. Practically, its findings provide a principled foundation for reforming OOW competency standards, updating maritime education curricula, and developing MASS-aligned regulatory frameworks within Indonesia's maritime governance architecture. The paper proceeds through a structured method section, followed by systematic results and analysis, an interpretive discussion, and a synthesizing conclusion.

2. METHOD

This study adopted a qualitative research design, a methodologically appropriate choice for investigating the complex, contested, and contextually embedded dimensions of MASS integration and OOW role transformation — phenomena that resist adequate characterization through quantitative enumeration and that require the interpretive depth, contextual sensitivity, and theoretical flexibility that qualitative inquiry affords (Braun & Clarke, 2006). The study drew on multiple data sources to enable triangulation and cross-perspective analysis, combining semi-structured stakeholder interviews with systematic document analysis of regulatory and policy texts. Research was conducted across institutional sites in Jakarta, including Sekolah Tinggi Ilmu Pelayaran (STIP) Jakarta and the Directorate General of Sea Transportation, selected purposively as Indonesia's primary centers of maritime officer training and domestic shipping regulatory governance respectively.

Three participant groups were recruited through purposive sampling to provide complementary perspectives on the study's three research objectives. The first group comprised twelve senior deck officers holding Class I or Class II Master Mariner certificates with documented experience on internationally operating vessels, selected to provide first-hand professional insight into the experiential and decision-making dimensions of OOW practice in increasingly automated and sensor-integrated bridge environments. The second group consisted of eight maritime education experts — senior lecturers and navigation instructors at STIP Jakarta with institutional responsibility for OOW competency training — recruited to assess the current alignment and gaps between maritime officer education curricula and MASS-related competency demands. The third group comprised five maritime regulatory practitioners from the Directorate General of Sea Transportation with direct involvement in Indonesia's domestic shipping regulatory development, providing authoritative perspectives on the governance and policy dimensions of MASS integration in Indonesian waters.

Data were generated through two primary instruments. The first was a semi-structured interview guide organized around three analytical dimensions corresponding to the study's research objectives: OOW role transformation and decision-making architecture under MASS autonomy; COLREGs compliance and collision avoidance challenges in Indonesian corridor contexts; and educational and regulatory preparedness for MASS integration. The second instrument was a document analysis protocol applied to the IMO MASS Code (MSC 107), the STCW Convention and Manila Amendments, Indonesian shipping regulatory instruments under Law No. 17/2008 on Shipping, and STIP Jakarta's current nautika study program

curriculum documentation. This protocol examined the provisions, gaps, and alignment between international MASS regulatory requirements and Indonesian national maritime governance frameworks.

Data analysis proceeded through three integrated procedures following established qualitative research principles. Thematic analysis was conducted on all interview transcripts using the systematic six-phase procedure of Braun and Clarke (2006), generating themes organized around OOW competency dimensions, MASS integration challenges, and institutional preparedness. Cross-group comparison was applied to identify convergences, tensions, and distinctive explanatory emphases across the officer, educator, and regulator datasets, enabling triangulated characterization of the research phenomena from multiple stakeholder vantage points. Narrative synthesis then integrated the thematic findings with the document analysis results into a coherent interpretive account of MASS integration implications for Indonesian maritime practice and education (Endsley, 1995; Wróbel et al., 2017).

3. RESULTS AND ANALYSIS

Findings are organized around three analytically distinct but interconnected dimensions: the transformation of OOW decision-making architecture under MASS autonomy, COLREGs compliance challenges in Indonesian corridor MASS encounter scenarios, and institutional preparedness assessments across maritime education and regulatory domains.

3.1 OOW Decision-Making Architecture Under MASS Autonomy

Document analysis of the IMO MASS Code combined with senior officer interview data generated a comparative framework of OOW decision-making demands across MASS autonomy degrees, as presented in Table 1. The framework maps the progressive redistribution of navigational decision authority from human officer to autonomous system across the four-degree MASS classification, while identifying the residual competency demands placed upon the OOW at each degree.

Table 1 *Comparative OOW Decision-Making Authority and Competency Demands Across MASS Autonomy Degrees*

MASS Degree	Operational Description	OOW Decision Authority	Primary Competency Demand	Situational Awareness Type
Degree 1	Automated decision support; crew on board	Full command; system advisory	Critical evaluation of AI recommendations	Direct environmental + system-mediated
Degree	Remote control;	Shared; officer	System monitoring;	Primarily system-

2	crew on board but not on bridge	intervenes on alert	remote override	mediated
Degree 3	Remote control; no crew on board	Remote; officer is sole supervisory authority	Remote situational assessment; emergency takeover	Entirely system-mediated
Degree 4	Full autonomy; no crew	No OOW; system autonomous	N/A (OOW role eliminated)	N/A

The most consequential finding emerging from this comparative analysis is the progressive shift in the *type* of situational awareness required of the OOW across MASS degrees. Under conventional and Degree One operation, the OOW exercises what Endsley (1995) classifies as direct environmental situational awareness — perceiving, comprehending, and projecting the navigational situation through direct sensory engagement with the physical bridge environment. Under Degree Two and Three MASS operation, this direct awareness is entirely replaced by system-mediated situational awareness: the officer's perception of the navigational environment is constructed exclusively through sensor data representations, camera feeds, AI-generated situation assessments, and digital communication relays — each of which introduces representational limitations, data latencies, potential sensor failures, and interpretive demands qualitatively different from those of direct bridge observation. Senior officer informants consistently identified this epistemological shift as the most disorienting and least adequately prepared-for aspect of MASS supervisory operation, describing a persistent and professionally unsettling sense of reduced perceptual confidence in the remote monitoring role.

3.2 COLREGs Compliance and Collision Avoidance in Indonesian Corridors

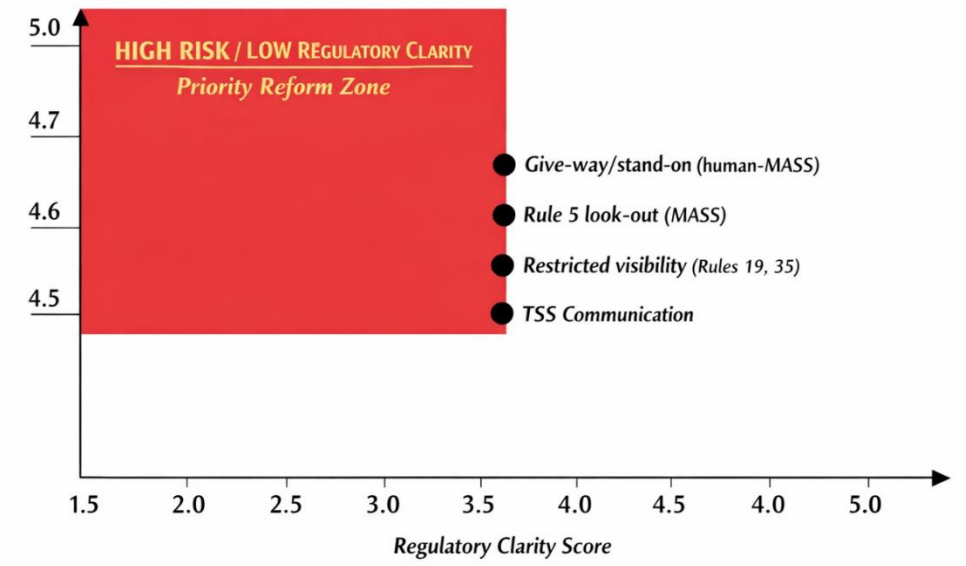
Thematic analysis of interview data and MASS Code document analysis identified four categories of COLREGs compliance challenge specific to MASS encounters in Indonesian shipping corridor conditions, as presented in Table 2.

Table 2 *COLREGs Compliance Challenge Categories in Indonesian Corridor MASS Encounter Scenarios: Frequency and Risk Severity Ratings*

COLREGs Challenge Category	Officer-Reported Frequency	Expert Risk Severity (1–5)	Regulatory Clarity Score (1–5)
Rule 5 look-out obligation interpretation for autonomous vessels	89%	4.6	1.8
Give-way/stand-on determination in human-MASS encounters	83%	4.7	2.1
Restricted visibility encounter protocols (Rules 19, 35)	76%	4.5	2.0
Communication obligation compliance in TSS/archipelagic lanes	71%	4.2	2.3

The lowest regulatory clarity scores — all below 2.5 on a 1–5 adequacy scale — indicate that across all four challenge categories, current IMO MASS Code provisions and Indonesian national shipping regulations offer inadequate interpretive guidance for real-world MASS encounter scenarios. The highest risk severity rating (4.7) was assigned to give-way/stand-on determination in human-MASS encounters, a finding reflecting the deep structural ambiguity created when an autonomous system programmed with COLREGs collision avoidance algorithms interacts with a conventionally manned vessel whose OOW is simultaneously attempting to apply the same rule set from a human interpretive standpoint — potentially generating conflicting action predictions and synchronized maneuver failures (Burmeister et al., 2014; Rødseth & Burmeister, 2012).

The Indonesian archipelagic corridor context intensifies these challenges in ways that international MASS research has not adequately characterized. Regulatory practitioners described Indonesian corridor conditions — including the simultaneous presence of large international carriers, small traditional wooden fishing vessels (perahu), domestic passenger ferries, and inter-island cargo ships in confined channel approaches — as creating encounter complexity that autonomous collision avoidance algorithms developed and tested in open-ocean or European short-sea shipping contexts are not demonstrably capable of managing within COLREGs parameters. This finding introduces a significant and previously undocumented contextual specificity to the MASS collision avoidance literature.



Note. Scores represent composite ratings from cross-group assessment.

Upper-left quadrant = **HIGH RISK / LOW REGULATORY CLARITY → Priority reform zone.**
All four challenge categories fall within the upper-left quadrant.

Figure 1: Risk Severity vs. Regulatory Clarity — COLREGs MASS Challenge Matrix

All four challenge categories fall within the upper-left quadrant.

The matrix confirms that all four COLREGs challenge categories fall within the high-risk, low-regulatory-clarity quadrant — a convergence that constitutes a compelling policy signal. No identified challenge category benefits from both adequate regulatory clarity and low risk severity, indicating a systemic governance gap rather than isolated interpretive ambiguities. This finding provides strong empirical support for the urgent development of MASS-specific COLREGs interpretive guidance calibrated to the Indonesian archipelagic operational context.

3.3 Institutional Preparedness: Maritime Education and Regulatory Frameworks

Cross-group comparison of maritime education expert and regulatory practitioner perspectives on institutional preparedness for MASS integration revealed consistent and mutually reinforcing assessments of systemic unpreparedness across both the educational and governance domains. Maritime education experts at STIP Jakarta uniformly assessed current Nautika curricula as MASS-unresponsive: the study program contains no dedicated modules on autonomous systems literacy, remote supervisory competency, MASS encounter decision-making, or the legal responsibilities of OOWs in MASS-integrated navigational environments. This assessment was corroborated by regulatory practitioners, who noted that Indonesia's primary shipping governance instrument — Law No. 17/2008 on Shipping — predates the IMO MASS Code by fifteen years and contains no provisions specifically addressing MASS operation, vessel registration, liability attribution, or operational licensing within Indonesian waters. The convergent finding — educational curricula MASS-blind, regulatory framework MASS-silent — establishes a dual institutional gap whose combined effect creates a structural unpreparedness for MASS integration whose severity exceeds that documented in comparable studies from European maritime contexts where at least nascent regulatory and curriculum adaptation processes are already underway (Felski & Zwolak, 2020).

4. DISCUSSION

The findings of this study converge on a single, analytically significant conclusion: Indonesia's maritime sector — its officer education system, its domestic regulatory framework, and its professional practice culture — is substantively and structurally unprepared for the MASS integration that the IMO MASS Code's 2028 entry into force will make operationally and legally unavoidable. This conclusion is not a judgment of institutional

failure in any narrow sense, but a characterization of the accumulated institutional lag that results when technological transformation at the global regulatory level outpaces the adaptive capacity of national maritime governance systems that were designed and resourced for an earlier operational era.

The transformation of OOW situational awareness from direct environmental to entirely system-mediated perception, documented in this study's findings, represents the most theoretically consequential dimension of MASS integration from a human factors and competency standpoint. Endsley's (1995) situational awareness framework identifies perception, comprehension, and projection as three sequential and interdependent processes through which operators develop the cognitive picture necessary for safe decision-making in dynamic environments. Under MASS Degree Three remote supervisory operation, the perceptual layer of this process is entirely redesigned: the officer no longer perceives the navigational environment directly but interprets a technologically constructed representation of it, mediated by sensor systems that have their own failure modes, coverage limitations, and data presentation logics. The implications for comprehension and projection — and therefore for the quality of emergency decision-making under MASS system failure conditions — are substantial and require empirical investigation beyond what the present study's qualitative scope has been able to generate. This gap represents a priority frontier for future MASS human factors research.

The COLREGs compliance findings extend and empirically contextualize the legal and technical scholarship of Burmeister et al. (2014) and Rødseth and Burmeister (2012), who have theoretically identified the interpretive tensions between MASS autonomous behavior and COLREGs human-officer provisions, by demonstrating that these tensions assume specific and intensified forms in the high-traffic, mixed-vessel-type environment of Indonesian archipelagic shipping corridors. The finding that give-way/stand-on determination in human-MASS encounters received the highest risk severity rating (4.7) and among the lowest regulatory clarity scores (2.1) in the Indonesian context is analytically significant: it establishes that the COLREGs ambiguity problem is not merely a theoretical legal puzzle but an operationally proximate safety risk whose likelihood of materialization is meaningfully elevated by the corridor traffic conditions of Indonesian waters. The absence of MASS-specific interpretive guidance in either the IMO MASS Code or Indonesian national shipping law constitutes a regulatory gap that this study makes visible with contextual specificity for the first time.

The dual institutional gap — curricula MASS-blind, regulatory framework MASS-

silent — documented in this study has direct implications for multiple stakeholder groups. For STIP Jakarta and comparable maritime education institutions, the findings provide a principled evidence base for advocating immediate curriculum revision to incorporate MASS-competency modules addressing autonomous systems literacy, remote supervisory decision-making, MASS-encounter COLREGs navigation, and the legal responsibilities of OOWs under the IMO MASS Code framework. For the Directorate General of Sea Transportation, the findings support the urgent development of a national MASS regulatory instrument — whether through amendment of Law No. 17/2008 or through dedicated ministerial regulation — that addresses vessel registration, operational licensing, liability attribution, and COLREGs interpretive standards for MASS operation in Indonesian waters. For the IMO STCW revision process, the study's evidence contributes to the growing international case for incorporating MASS-specific competency standards into the STCW framework — a process that has been initiated but remains incomplete at the time of writing (IMO, 2021; Wróbel et al., 2017).

The study's acknowledged limitations include its qualitative scope and single-country institutional focus, which constrain the generalizability of findings to other national MASS integration contexts. The absence of real-world MASS operational data from Indonesian waters — reflecting the fact that commercial MASS deployment in Indonesian corridors has not yet occurred — means that the COLREGs challenge and situational awareness findings rest on expert assessment and scenario-based reasoning rather than empirical incident analysis. Future research should combine real-world MASS trial data, simulator-based human factors experimentation, and longitudinal curriculum evaluation to build the more comprehensive and quantitatively grounded evidence base that MASS integration policy demands.

5. CONCLUSION

This study has demonstrated that the integration of Maritime Autonomous Surface Ships into Indonesian shipping corridors generates four structurally consequential and institutionally unresolved challenges: the epistemological transformation of OOW situational awareness under remote supervisory MASS operation, systemic COLREGs compliance ambiguities in human-MASS encounter scenarios specific to Indonesian archipelagic conditions, the complete absence of MASS-responsive curriculum provision within Indonesian maritime officer education, and the regulatory silence of Indonesian national shipping law on MASS governance. These findings, generated through cross-group

qualitative analysis of senior officer, maritime education expert, and regulatory practitioner perspectives, establish with contextual specificity that Indonesia's maritime sector faces a compounded and urgent institutional lag relative to the MASS regulatory transformation that the IMO MASS Code's 2028 entry into force will activate. The study contributes a theoretically grounded, empirically substantiated argument for the simultaneous and coordinated reform of OOW competency standards, maritime education curricula, and national MASS regulatory frameworks within Indonesian maritime governance — reforms whose urgency is directly proportional to the safety stakes of MASS integration in one of the world's most complex and strategically significant maritime corridor environments.

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