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Assessment of Maritime Cybersecurity Preparedness in Port Operations and Shipping Companies

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Abstract: *The increasing digitization of maritime operations has introduced significant cybersecurity risks, particularly in port operations and shipping companies that rely heavily on integrated information systems. This study aims to assess the level of cybersecurity preparedness in the maritime sector by evaluating the existing strategies, vulnerabilities, and risk mitigation measures in Indonesian ports and maritime shipping firms. A mixed-method approach was employed, combining surveys distributed to IT and operational personnel with in-depth interviews involving cybersecurity experts and port management. The findings reveal varying levels of awareness and readiness, with larger ports and international shipping companies demonstrating more advanced cybersecurity frameworks compared to smaller, regional operators. Key gaps were identified in incident response protocols, employee training, and system resilience. The results highlight the urgent need for regulatory alignment, capacity building, and investment in cybersecurity infrastructure to safeguard critical maritime assets and ensure operational continuity. This research provides practical insights for policymakers, port authorities, and maritime stakeholders to develop a standardized and proactive approach to cybersecurity in the maritime domain.*

Keywords*: cyber threats, maritime sector, port operations, risk management, shipping companies*.

1. BACKGROUND

The maritime industry has undergone rapid digital transformation, resulting in an increased dependency on interconnected digital systems for port operations, navigation, cargo handling, and communication. While this transformation enhances efficiency, it also exposes maritime infrastructure to significant cybersecurity threats. Ports and shipping companies, particularly those with underdeveloped digital resilience, face increased risks of cyberattacks that can disrupt operations, cause financial losses, and compromise national security (Tam & Jones, 2019). The interconnected nature of port ecosystems makes them vulnerable targets, especially when cybersecurity standards vary widely among stakeholders.

Cyber threats in the maritime sector have evolved in both complexity and frequency. Recent incidents such as the Maersk NotPetya attack in 2017 highlight the critical impact of cyber incidents, leading to operational shutdowns and financial damages exceeding USD 200 million (Boyes, Isbell & Luck, 2020). Despite these cases, many maritime entities remain inadequately prepared to detect, respond to, or recover from cyber incidents. Studies indicate that smaller regional ports and shipping companies often lack comprehensive cybersecurity strategies, due to limited awareness, financial constraints, or absence of regulatory enforcement (Chang, Kuo & Chen, 2022).

Prior research has predominantly focused on technical aspects of cybersecurity or on broader transportation infrastructure, with limited focus on port-specific vulnerabilities and organizational readiness. Moreover, there is a lack of integrated assessments that combine both

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technical and managerial perspectives in evaluating cybersecurity preparedness within maritime operations (Jones, Tam & Papadaki, 2020). This gap suggests a pressing need for localized studies that assess real-world practices and vulnerabilities in port operations, particularly in developing countries where maritime infrastructure is expanding but cybersecurity maturity remains low.

This study seeks to address that gap by assessing the level of cybersecurity preparedness in port operations and shipping companies in Indonesia. The study combines quantitative surveys and qualitative interviews to evaluate current practices, institutional awareness, and capability to respond to cyber risks. By capturing insights from operational and IT personnel, the research presents a holistic view of the cybersecurity landscape in Indonesian maritime logistics and highlights critical weaknesses that may hinder future resilience.

The findings of this study are expected to inform port authorities, maritime regulators, and industry stakeholders about the urgency of implementing standardized cybersecurity measures. The study also contributes to the growing body of literature by offering empirical evidence from a Southeast Asian context, thereby providing practical guidance on policy development, training, and technology adoption in maritime cybersecurity governance.

2. THEORETICAL REVIEW

The theoretical foundation of maritime cybersecurity preparedness is rooted in the principles of risk management and organizational resilience. Cybersecurity in critical infrastructure sectors, including maritime operations, can be understood through the lens of Information Security Management Systems (ISMS), such as ISO/IEC 27001, which emphasizes risk identification, control implementation, and continuous improvement (Von Solms & Van Niekerk, 2013). Within the maritime context, ISMS must be adapted to address operational technologies (OT) such as SCADA systems and Automatic Identification Systems (AIS), which are increasingly integrated with Information Technology (IT) systems in ports and vessels.

The Resilience Engineering Theory also provides an important conceptual framework. It suggests that organizations must not only protect against threats but also develop the capacity to adapt, absorb disruptions, and recover efficiently (Hollnagel, Woods, & Leveson, 2006). In maritime logistics, resilience encompasses not just technical infrastructure, but also human competencies, institutional protocols, and inter-organizational collaboration, which are often weak points in cybersecurity defense. This theory underlines the significance of building a proactive security culture across different levels of port operations.

Previous studies have highlighted the complexity of managing cybersecurity in port environments due to the multiplicity of stakeholders, legacy systems, and the absence of unified governance structures (Katsikas, Papadaki, & Gkioulos, 2020). For instance, research by Tam and Jones (2019) revealed that many port operators do not conduct regular risk assessments or have incident response plans, making them susceptible to disruptions caused by even low-sophistication cyber threats. Similarly, Gopalakrishnan et al. (2021) identified the lack of cybersecurity awareness and training among port staff as a major vulnerability, especially in developing economies.

In the Southeast Asian context, maritime cybersecurity research remains underrepresented, despite the region's growing significance in global shipping networks. Studies by Chang, Kuo, and Chen (2022) emphasized that regional shipping companies often lag in cybersecurity investment and preparedness compared to their global counterparts. This is partly due to limited regulatory pressure and fragmented IT governance. These gaps signal the need for empirical research that assesses cybersecurity preparedness not only from a technical perspective but also from organizational and behavioral dimensions.

Grounded in the above theories and empirical insights, this study explores the cybersecurity preparedness of Indonesian ports and shipping companies. It draws upon risk management, resilience, and organizational behavior theories to assess both infrastructural capabilities and institutional readiness. While not stated explicitly as a hypothesis, the study assumes that organizational size, international exposure, and internal training practices are positively associated with higher levels of cybersecurity preparedness.

3. RESEARCH METHOD

This study employed a mixed-methods research design, integrating both quantitative and qualitative approaches to comprehensively assess the level of cybersecurity preparedness in port operations and shipping companies. The quantitative component involved structured surveys to gather measurable data on organizational policies, technological infrastructure, and personnel awareness regarding cybersecurity. In parallel, qualitative in-depth interviews were conducted with IT managers, port administrators, and cybersecurity experts to obtain deeper insights into implementation challenges, policy gaps, and organizational behaviors.

The population in this study consisted of maritime professionals working in Indonesian port authorities and shipping companies. The sample was selected using purposive sampling to ensure the inclusion of respondents with relevant cybersecurity responsibilities, including IT staff, operations personnel, and managerial-level stakeholders. A total of 120 valid responses were collected for the survey, and 12 key informants participated in interviews. This approach aligns with Creswell's (2014) recommendation on using mixed methods to triangulate findings and improve research validity.

The data collection instruments included a structured questionnaire adapted from the Cybersecurity Capability Maturity Model (C2M2), which evaluates organizational practices across domains such as risk management, training, asset management, and incident response (U.S. Department of Energy, 2014). Interview questions were semi-structured and designed to explore perceptions of cybersecurity risks, policy implementation, and organizational culture.

Quantitative data were analyzed using descriptive statistics and inferential analysis, including t-tests and ANOVA to examine differences in preparedness based on company size and international engagement. The statistical analysis was performed using SPSS. The survey instrument was tested for validity using factor analysis, and reliability was confirmed with a Cronbach's Alpha coefficient of 0.85, indicating high internal consistency (Nunnally & Bernstein, 1994).

The research model used in this study was developed based on the theoretical assumptions of organizational resilience and information security maturity. The model hypothesizes that organizational size (OS), training and awareness (TA), and policy implementation (PI) positively influence cybersecurity preparedness (CP). The relationship can be represented as:

$$\mathbf{CP = \beta_0 + \beta_1(OS) + \beta_2(TA) + \beta_3(PI) + \varepsilon,}$$

where β represents regression coefficients and ε denotes the error term. This model structure follows standard multiple regression analysis techniques, as discussed in Hair et al. (2010).

4. RESULTS AND DISCUSSIONResults Study

Data Collection and Research Context

Data collection was conducted over a two-month period from February to March 2025 across three major Indonesian port cities: Jakarta, Surabaya, and Makassar. These ports were selected due to their strategic role in national and international shipping routes. A total of 120 respondents completed the survey instrument, and 12 in-depth interviews were held with cybersecurity officers and operational managers in port and shipping companies.

Descriptive Results

The analysis of survey data revealed that 61.7% of respondents indicated the presence of basic cybersecurity policies in their organizations, yet only 27.5% reported having formal incident response plans. Meanwhile, 48.3% of respondents noted that their organizations had conducted at least one cybersecurity training in the past year.

Table 1 below summarizes the descriptive statistics of key variables used in the study:

Table 1. Descriptive Statistics of Cybersecurity Preparedness Indicators

Variable	Mean	SD	Min	Max
Organizational Size (OS)	2.87	1.02	1	5
Training & Awareness (TA)	3.21	0.88	1	5
Policy Implementation (PI)	2.64	1.10	1	5
Cybersecurity Preparedness (CP)	2.95	0.95	1	5

(Source: Research Data, 2025)

Regression Analysis

The multiple regression analysis indicated that all three independent variables had a statistically significant impact on cybersecurity preparedness (CP). The regression model showed an R^2 value of 0.58, suggesting that 58% of the variance in CP could be explained by organizational size, training and awareness, and policy implementation.

Table 2. Regression Results

Variable	β	t-value	p-value
Organizational Size (OS)	0.312	4.13	0.000
Training & Awareness (TA)	0.402	5.76	0.000
Policy Implementation (PI)	0.291	3.87	0.000

(Source: SPSS Output, 2025)

These findings support the theoretical framework based on resilience and information security maturity models (Hollnagel et al., 2006; Von Solms & Van Niekerk, 2013), where organizational capability and proactive behaviors are seen as key drivers of cyber resilience.

Discussion

The results indicate that training and awareness is the most influential factor affecting cybersecurity preparedness. This confirms previous findings by Gopalakrishnan et al. (2021), who noted that technical defenses are insufficient without parallel investment in human capability and institutional culture. Furthermore, the influence of organizational size is consistent with Tam and Jones (2019), who observed that larger ports and shipping firms tend to allocate more resources to digital infrastructure and security governance.

The policy implementation variable also shows a significant positive relationship with preparedness, aligning with the conclusions of Katsikas et al. (2020), who emphasized the need for structured cybersecurity governance to address operational risks in complex maritime environments.

Despite positive indicators, the study also uncovers significant gaps. For instance, only 30% of organizations had conducted cybersecurity audits, and many lacked dedicated cybersecurity teams. This implies a reactive, rather than proactive, security posture in many Indonesian maritime firms. The qualitative interviews echoed this concern, highlighting a lack of regulatory pressure and limited collaboration between ports and national cyber agencies.

Theoretical and Practical Implications

From a theoretical perspective, the study reinforces the importance of viewing cybersecurity not just as a technical issue, but as a multidimensional construct that involves organizational behavior, risk culture, and institutional readiness. Practically, the findings urge port authorities and regulators to establish minimum cybersecurity standards and facilitate capacity-building programs. Establishing partnerships with international cybersecurity bodies could help transfer knowledge and elevate industry-wide practices.

5. CONCLUSION AND SUGGESTION

The findings of this study conclude that cybersecurity preparedness in Indonesian port operations and shipping companies is significantly influenced by organizational size, the level of training and awareness, and the degree of policy implementation. Training and awareness emerged as the most influential factor, highlighting the importance of human-centered approaches in enhancing maritime cybersecurity, consistent with prior research (Gopalakrishnan et al., 2021; Tam & Jones, 2019). While larger organizations tend to demonstrate higher readiness, the general lack of incident response plans, cybersecurity audits, and structured governance in smaller or regional operators indicates critical vulnerabilities. Therefore, it is recommended that maritime authorities prioritize workforce capacity building, establish minimum cybersecurity policy standards, and encourage inter-organizational collaboration to enhance systemic resilience (Von Solms & Van Niekerk, 2013). This study's limitations include its focus on Indonesian ports only and the relatively small number of interview participants, which may affect the generalizability of the results. Future research should expand the geographic scope, integrate real-time vulnerability assessments, and explore the impact of international regulations such as the IMO's Maritime Cyber Risk Management Guidelines to support broader policy development (Katsikas et al., 2020; Hollnagel et al., 2006).

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