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Digitalization and Risk Management in Intelligent Ship Operations: Implications for Sea Transportation Safety Management

Iksan Saifudin[1] , Jaya Alamsyah[1]*
[1] North Sulawesi Maritime Polytechnic, South Minahasa Regency, Indonesia

Alamat: JL. Trans Sulawesi KM.80 Desa Tawaang Kec. Amurang, Kab. Minahasa Selatan Sulawesi Utara
**Korespondensi penulis: jaya.alamsyah@gmail.com*

Abstract. *The digitalization of sea transportation, encompassing intelligent ship systems, port information sharing, and artificial-intelligence-assisted planning, is reshaping how safety and operational risk are managed in maritime settings. This paper examines digitalization and risk management in intelligent ship operations as they bear on sea transportation safety management, using Politeknik Pelayaran Sulawesi Utara (Poltekpel Sulut) as a reflective case setting for training activity between April 2025 and January 2026. The paper synthesizes the literature on intelligent ship risk scenarios, artificial-intelligence-assisted logistics planning, and smart port information sharing with institutional document review and field observation at Poltekpel Sulut. It finds that digital and intelligent-systems content is present in the training environment primarily as operational instruction on using digital tools, while the risk-management competency needed to reason about failure modes of those same systems is comparatively underdeveloped. The paper argues that as sea transportation in Indonesia adopts increasingly automated and data-driven systems, maritime training providers need to shift emphasis from tool operation toward structured risk reasoning about digital and intelligent systems, and proposes a framework for sequencing this shift within existing curricula.*

Keywords: *digitalization, intelligent ships, risk management, sea transportation safety, artificial intelligence, maritime education*

1. Introduction

Sea transportation is undergoing a digitalization shift comparable to that experienced by other logistics-intensive sectors, with intelligent ship systems, artificial-intelligence-assisted planning tools, and networked port information systems becoming increasingly common features of vessel and port operation. This shift brings efficiency and safety benefits, but it also introduces new categories of operational risk that differ from the risks associated with conventional, non-digitalized shipping, including software failure modes, data quality dependencies, and the risk of overreliance on automated decision support in situations the underlying system was not designed to handle.

For a maritime training institution such as Politeknik Pelayaran Sulawesi Utara (Poltekpel Sulut), this shift raises a specific management question: does current training adequately prepare cadets not only to operate digital and intelligent systems but also to reason about how those systems can fail and what risk-management response is appropriate when they do? This paper examines that question using Poltekpel Sulut's training activity between April 2025 and January 2026 as a reflective case setting, drawing on the literature on intelligent ship risk scenarios, artificial-intelligence-assisted logistics

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forecasting, and smart port information sharing to interpret institutional documentation and field observation from the stated period.

2. Literature Review

2.1 Risk Scenarios in Intelligent Ship Operations

Zhang et al. (2022) develop a risk scenario evaluation framework specifically for intelligent ships, arguing that the introduction of automated navigation and decision-support systems changes the character of maritime risk rather than simply reducing it. Their analysis identifies scenarios in which automated systems perform reliably under normal operating conditions but degrade unpredictably under edge cases such as sensor conflict, degraded communications, or unusual traffic patterns, and they argue that crew training needs to specifically address these edge-case scenarios rather than assuming that competence in normal-condition operation transfers automatically to crisis conditions. This distinction between normal-condition competence and edge-case risk reasoning is central to the argument developed in this paper.

The practical implication of Zhang et al.'s (2022) framework for maritime education is that risk training for intelligent ship systems cannot be adequately delivered through operational instruction alone; it requires deliberately constructed failure scenarios that force trainees to recognize when a digital system's output should be questioned or overridden, a competency that is qualitatively different from learning to operate the system under ordinary conditions.

2.2 Artificial Intelligence in Logistics Planning and Demand Forecasting

Chae et al. (2021), applying meta-analysis and artificial-intelligence methods to demand forecasting for liquefied natural gas bunkering, demonstrate that AI-assisted forecasting can materially improve planning accuracy in maritime logistics, but they also note that forecast quality is highly sensitive to the quality and representativeness of the underlying data, meaning that AI-assisted planning tools can produce confidently wrong outputs when applied in contexts that differ from their training data. Elbouzidi et al. (2023), reviewing the role of artificial intelligence in warehouse digital twin systems, reach a similar conclusion in a logistics context, noting that digital twin and AI-assisted planning tools deliver their greatest value when paired with human oversight capable of recognizing when the digital model has diverged from physical reality. Both studies point toward the same management implication as the intelligent ship risk literature: digital and AI-assisted tools shift risk rather than eliminate it, and the shifted risk is one of misplaced confidence in system output.

2.3 Smart Port Information Sharing and Institutional Coordination

Sijabat and Simanjuntak (2025), examining collaboration and information sharing in smart eco-ports, find that the safety and efficiency benefits of digital information-sharing systems depend on institutional coordination between the organizations that feed data into the system, since a digitalized port information system is only as reliable as the weakest data source feeding it. Cahyadi et al. (2025), in their stakeholder-based analysis of sustainability and innovation in maritime vocational education, similarly argue that technology adoption in maritime training settings succeeds only where institutional stakeholders are aligned on how the technology will be used and maintained, reinforcing that the risk-management dimension of digitalization is as much an institutional coordination problem as a technical one.

3. Methodology

This paper uses a qualitative, case-based management analysis of digitalization-related training content and practice at Poltekpel Sulut between April 2025 and January 2026. Curriculum and training-schedule documentation was reviewed to identify where digital and intelligent-systems content appears in cadet training, distinguishing content oriented toward tool operation from content oriented toward risk reasoning about system failure. Field observation of simulator-based and classroom training during the stated period supplemented this review with descriptive accounts of how digital-systems content was taught and practiced. These institutional findings were then interpreted against the intelligent ship risk, AI-assisted logistics, and smart port coordination literature reviewed above.

4. Results and Discussion

4.1 Digital Tool Operation Is Well Represented in Training

Simulator and classroom-based training at Poltekpel Sulut during the observed period included substantial content on operating digital navigation and communication tools, consistent with the general expectation that maritime training providers prioritize familiarity with the digital equipment cadets will encounter aboard modern vessels. This operational emphasis mirrors the tool-operation focus that Chae et al. (2021) and Elbouzidi et al. (2023) note is the more commonly developed competency in AI-assisted logistics and planning contexts more broadly, suggesting that Poltekpel Sulut's approach is consistent with prevailing practice rather than unusual for the sector.

4.2 Edge-Case Risk Reasoning Remains a Gap

Consistent with the pattern identified by Zhang et al. (2022), document review found limited structured content addressing edge-case failure of intelligent systems, such as scenarios where automated navigation aids conflict with visual or radar information, or where AI-assisted planning outputs should be treated with scepticism because of unusual input conditions. Training content tended to treat digital systems as reliable instruments to be operated correctly rather than as systems whose outputs require active verification. This is a natural pattern in a training environment where instructional time is limited and where teaching correct operation is a prerequisite before teaching failure-mode reasoning, but it does represent the principal gap identified in this case analysis, and it is the gap most directly relevant to sea transportation safety management as intelligent systems become more prevalent in the domestic fleet.

Addressing this gap does not necessarily require additional instructional hours; following Zhang et al.'s (2022) framework, existing simulator exercises could be adapted to periodically inject conflicting or degraded sensor data, requiring cadets to practice recognizing when a digital system's recommendation should be questioned, which builds risk-reasoning competency within the time already allocated to digital-systems training rather than as a separate module.

4.3 Institutional Coordination as a Precondition for Safe Digitalization

Observation of Poltekpel Sulut's engagement with regional port and shipping stakeholders during the study period suggested emerging but still developing coordination on digital information sharing, consistent with the coordination-dependency argument of Sijabat and Simanjuntak (2025). Given that the safety value of a smart port information system depends on the reliability of every contributing data source, this paper suggests that Poltekpel Sulut has an opportunity to position itself as a data-quality and training partner within a wider regional smart port information network, consistent with the stakeholder-alignment argument of Cahyadi et al. (2025), rather than treating digitalization purely as a matter of acquiring new equipment for the training fleet.

5. Conclusion

Digitalization in sea transportation shifts rather than eliminates operational risk, and safety management in an increasingly digital and intelligent-systems-oriented maritime sector depends on training that builds risk-reasoning competency alongside tool-operation competency. The case of Poltekpel Sulut over April 2025 to January 2026 indicates that current training practice is comparatively strong on tool operation but has

room to develop structured edge-case risk reasoning, a gap that can plausibly be addressed by adapting existing simulator exercises rather than by adding new curriculum hours. Institutional coordination on data quality within regional smart port information networks emerges as a complementary priority, positioning maritime training providers as active contributors to the safety of digitalized sea transportation systems rather than passive adopters of digital tools. Future work could evaluate cadet performance in edge-case simulator scenarios before and after curriculum adaptation to test whether this approach measurably improves risk-reasoning competency.

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