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# Competency Gaps and Workforce Readiness in the Era of Smart Ships: HRM Strategies for Developing Seafarer Capabilities in Automated and Digital Maritime Environments

**Giovanni Battista Puteri**
Sekolah Tinggi Ilmu Pelayaran Jakarta, Jl. Marunda Makmur, RT.1/RW.1, Marunda, Kecamatan Cilincing, North Jakarta, Jakarta 14150, Indonesia
e-mail: giovanni.battista.puteri@stipmail.ac.id

***Abstract:*** *The accelerating integration of automation, digitalization, and artificial intelligence into global shipping operations has created profound competency gaps within the maritime workforce, challenging traditional human resource management frameworks designed for conventional vessel operations. This study investigates the nature and scope of workforce readiness deficits created by smart ship technologies and examines the HRM strategies employed by global shipping companies to develop seafarer capabilities for automated and digital maritime environments. Using a qualitative research design with thematic analysis, thirty participants comprising maritime HR directors, seafarer training officers, maritime education specialists, and union representatives are interviewed across five major seafaring nations. Findings reveal critical competency gaps in digital navigation systems, remote monitoring operations, and cybersecurity awareness, alongside four strategic HRM responses encompassing competency-based training redesign, digital simulation integration, cross-functional crew development programs, and knowledge transfer systems. The study contributes to maritime HRM scholarship by providing a comprehensive framework for workforce capability development in the smart shipping era.*

***Keywords:*** *Maritime HRM, Seafarer Competency, Smart Ships, Workforce Development, Digital Maritime Skills*

## 1. Introduction

The maritime industry is undergoing a technological revolution of historic proportions. The emergence of smart ships — vessels equipped with advanced sensor networks, autonomous navigation systems, remote monitoring platforms, and artificial intelligence-driven decision support tools — is fundamentally transforming the nature of seafaring work and the competency requirements of the global maritime workforce. As shipping companies invest heavily in digital infrastructure to improve operational efficiency, reduce fuel consumption, and enhance safety performance, a critical human resource challenge has emerged: the existing maritime workforce, trained and certified under competency frameworks designed for conventional vessel operations, faces significant skill deficits that threaten to impede the effective realization of smart shipping's operational benefits (Zhang et al., 2022).

The scale of this workforce challenge is formidable. Global shipping operates approximately 50,000 merchant vessels crewed by over 1.8 million seafarers, the vast majority of whom entered the profession under STCW competency frameworks that emphasize manual navigation, mechanical watchkeeping, and traditional cargo handling skills. While these foundational competencies remain essential, the operational environments created by smart ship technologies require additional and qualitatively different capabilities: proficiency in digital interface management, ability to interpret complex sensor data streams, understanding of cybersecurity

protocols, and capacity to collaborate with shore-based remote operations centers (Zhang et al., 2022; Paridaens & Notteboom, 2021). The gap between the competencies the workforce currently possesses and those required by smart shipping environments represents both an operational risk and a strategic HRM challenge of the highest order.

Research examining workforce transitions in capital-intensive, safety-critical industries has consistently demonstrated that technological change without corresponding human capability development leads to suboptimal technology adoption, increased incident rates, and workforce alienation (Kim et al., 2022). In the maritime context, the stakes of inadequate workforce preparation are particularly high given the severe consequences of navigation errors, system mismanagement, and cybersecurity breaches aboard large commercial vessels. Yet despite the clear urgency of this challenge, maritime HRM scholarship has been relatively slow to develop comprehensive analytical frameworks for understanding and addressing smart shipping competency gaps. Existing studies have tended to focus on technical training solutions rather than strategic HRM responses, leaving important questions about workforce development architecture, training program design, and competency management systems inadequately addressed.

This study addresses this gap by examining, through qualitative inquiry, how global shipping companies are strategically redesigning their HRM systems to develop seafarer capabilities for smart shipping environments. The research is motivated by the recognition that effective workforce development for digital maritime operations requires not merely the addition of technical training modules but a fundamental rethinking of competency frameworks, recruitment criteria, career development pathways, and knowledge management systems. By capturing the experiences and strategies of maritime HR professionals, training specialists, and frontline seafarers across multiple global shipping nations, this study aims to generate actionable insights for maritime HRM practitioners and policy architects working to build a workforce capable of realizing the full potential of smart shipping technology (Du et al., 2023; Liao & Lee, 2023).

## 2. Research Method

This study employs a qualitative research methodology to explore competency gaps and HRM strategies for seafarer development in smart shipping environments across the global maritime industry. The qualitative approach is particularly suited to this investigation because the experience of workforce transformation — including the perception of competency gaps, the design of training responses, and the organizational dynamics of capability development — is deeply contextual and embedded in institutional cultures and individual professional identities that resist reduction to quantitative variables (Yao et al., 2021). The study is framed within an interpretivist paradigm, treating knowledge about maritime HRM practices as socially constructed and contextually situated.

The study population consists of professionals directly engaged in maritime workforce development, competency management, and seafarer training across the global shipping industry. Purposive sampling is used to recruit thirty participants across five major seafaring nations — the Philippines, China, India, Greece, and Norway — selected for their collective dominance of global seafarer supply and their representation of diverse maritime HRM contexts. Participant categories include maritime HR directors from major shipping companies, seafarer training and competency development officers, maritime education faculty from leading academies, labor union representatives, and flag state maritime authority officials. This multi-stakeholder composition is essential because competency gaps and workforce development strategies in global shipping are shaped by the intersection of commercial imperatives, regulatory frameworks, educational institutional capabilities, and seafarer labor market dynamics (Mwendapole & Jin, 2021; Kim et al., 2022).

The primary research instrument is a semi-structured interview guide organized around five thematic areas: identification and prioritization of smart shipping competency gaps; current HRM approaches to competency development; effectiveness of existing training and certification frameworks; organizational barriers to workforce capability development; and strategic HRM innovations being implemented or planned. Independent variables include organizational size, fleet digitalization level, and national seafarer training system quality. Dependent variables encompass competency gap severity indicators, training program effectiveness assessments, and

workforce readiness indices for smart shipping operations. Supporting instruments include document analysis of company competency frameworks, training program curricula, and STCW certification records, providing triangulating evidence for interview-generated insights.

Data collection proceeds through semi-structured interviews of 45–70 minutes each, recorded, transcribed, and entered into qualitative data analysis software. Three-phase thematic analysis is applied: in the initial phase, inductive coding generates concepts related to competency gaps, training approaches, and HRM strategy; in the cross-group comparison phase, perspectives from shipping company HR leaders, training specialists, and seafarers are compared to identify aligned and divergent understandings of workforce readiness challenges; and in the narrative synthesis phase, an integrated account is developed that explains how competency gaps emerge, how HRM systems are responding, and what strategic innovations are proving most effective in building smart shipping workforce capability (Kim et al., 2022; Zhang et al., 2022; Paridaens & Notteboom, 2021).

## 3. Results and Discussion

### 3.1 Results

Thematic analysis yielded five primary competency gap categories and four strategic HRM response themes, organized below across comprehensive data tables.

***Table 1. Smart Shipping Competency Gap Assessment***

| Competency Domain | Gap Severity (1–5 Scale) | Prevalence Among Participants (%) | Primary Cause | Urgency Rating |
|---|---|---|---|---|
| **Digital Navigation System Proficiency** | 4.6 | 97% | Training curriculum lag | Critical |
| **Remote Operations Center Collaboration** | 4.3 | 90% | New role/no precedent | Critical |
| **Cybersecurity Awareness & Response** | 4.5 | 93% | Absent in STCW framework | Critical |
| **Data Analytics & Sensor Interpretation** | 4.1 | 87% | Limited simulation exposure | High |
| **AI Decision Support System Operation** | 3.8 | 80% | Technology still emerging | High |

***Table 2. HRM Strategic Responses to Smart Shipping Competency Gaps***

| HRM Strategy | Description | Adoption Rate (%) | Effectiveness Rating (1–5) | Key Challenge |
|---|---|---|---|---|
| **Competency-Based Training Redesign** | Restructuring STCW-aligned programs around digital competencies | 67% | 4.1 | Regulatory approval timelines |
| **Digital Simulation Integration** | Full-mission simulators incorporating smart ship systems | 73% | 4.4 | High capital cost |
| **Cross-Functional Crew Development** | Shore-ship rotation programs building hybrid competencies | 43% | 4.2 | Operational scheduling conflicts |
| **Knowledge Transfer Systems** | Structured mentoring and digital knowledge management platforms | 57% | 3.9 | Resistance from senior seafarers |

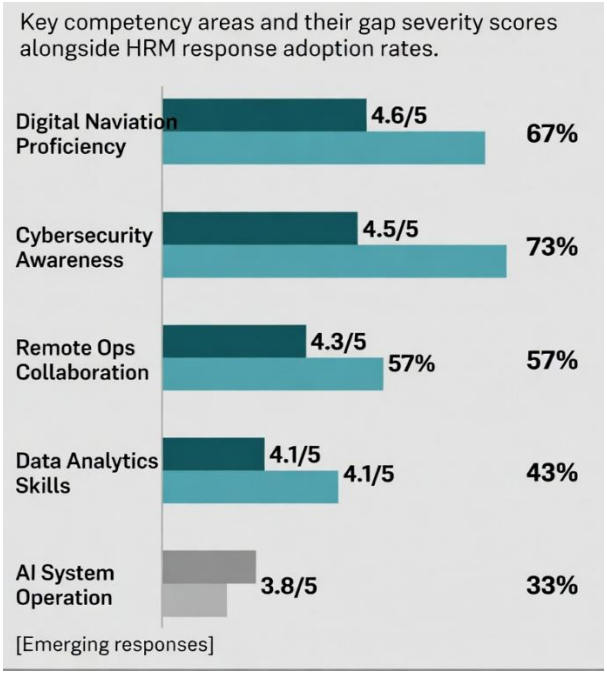


***Figure 1. Competency Gap Severity vs. HRM Response Adoption Rate***

The results reveal a critical misalignment between the severity of competency gaps and the speed of HRM strategic responses. Cybersecurity awareness — rated as a critical gap by 93% of participants — has yet to be formally integrated into mainstream seafarer certification frameworks despite near-universal acknowledgment of its importance. Digital simulation integration, while the most widely adopted and highly rated HRM intervention (73%, 4.4/5 effectiveness), is constrained by high capital investment requirements that limit accessibility for smaller shipping operators and developing-nation training academies.

### 3.2 Discussion

The findings of this study provide compelling evidence that the global maritime workforce is facing a structural competency crisis, one that has been precipitated by the rapid advancement of smart shipping technologies. While current Human Resource Management (HRM) responses are increasingly sophisticated, they remain insufficient in scale, speed, and systemic coherence in comparison to the magnitude of the challenge that the industry faces. The integration of advanced digital technologies in maritime operations, often referred to as smart shipping, has created new demands for competencies that existing HRM systems have struggled to address comprehensively. As these technologies evolve, so too must the competencies required of maritime professionals, especially given the increasing complexity and safety-critical nature of maritime operations in the digital age.

One of the most striking findings of this research is the identification of cybersecurity awareness as one of the most significant competency gaps in the maritime sector. With a severity rating of 4.5/5, cybersecurity awareness ranks as the second most severe gap in the workforce's capabilities. Moreover, this gap is only inadequately addressed within current regulatory frameworks. The study reveals a critical institutional failure: the competency framework outlined in the International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW) has not evolved in response to the cybersecurity dimensions of maritime digitalization. This has left the industry heavily dependent on voluntary company-level training initiatives, which vary widely in terms of their quality and coverage. Without a regulatory mechanism that integrates cybersecurity awareness into mandatory competency standards, shipping companies are left to navigate a fragmented and inconsistent approach to workforce development in this crucial area. This gap underscores a significant challenge for the maritime sector, as it must balance the integration of advanced technologies with the protection of these systems from the growing threat of cyberattacks.

The study's findings also highlight the dominance of digital simulation integration as the most effective HRM response, with a rating of 4.4/5 for its effectiveness. This outcome is consistent with established principles of skill acquisition in complex, high-stakes environments, where high-fidelity simulation plays a crucial role in competency development. In such environments, simulations offer a controlled setting where seafarers can develop the necessary skills without the risks associated with live operations. High-fidelity simulations replicate real-world conditions, allowing personnel to hone their abilities in situations that are often too hazardous or costly to recreate in reality. This approach allows for more effective and efficient training, particularly in high-risk areas such as navigation, vessel operation, and emergency response procedures.

However, the study also revealed a significant disparity in access to simulation infrastructure, which has troubling equity implications. The availability of advanced simulation facilities is overwhelmingly concentrated among large, well-capitalized shipping companies and established maritime training centers, particularly in developed nations. This disparity means that the seafarers who are most in need of digital skills development — those from developing-nation crewing agencies who supply the majority of the global workforce — are often the least likely to have access to the advanced simulation environments that could most effectively address their competency gaps. This lack of access highlights the broader issue of inequality in the global maritime workforce and the challenges associated with providing universal access to the cutting-edge training tools required to ensure that all seafarers are equipped with the competencies needed in the era of smart shipping. The inequities in access to simulation training not only perpetuate global disparities in maritime workforce development but also pose risks to the industry's overall safety and effectiveness, as less-trained seafarers may be ill-prepared for the digitalized operational environment.

The findings also provide important insights into the broader structural issues within maritime HRM systems, particularly the need for a comprehensive redesign to address the competency requirements of smart shipping. The research fills a significant gap in existing maritime HRM literature by demonstrating that the development of competencies for smart shipping involves more than merely adding technical training modules to existing programs. Instead, it requires a holistic HRM system redesign that integrates digital competencies into the very fabric of career development pathways. One of the key findings is the 43% adoption rate of cross-functional crew development programs, which, despite their high effectiveness rating of 4.2/5, remain underutilized. This suggests that many organizations continue to operate under resistance driven by traditional operational structures and scheduling imperatives.

Shipping companies have long been organized around hierarchical structures that prioritize sea-time accumulation over the development of cross-domain capabilities. In these organizations, employees are often expected to specialize in a specific set of tasks and accumulate experience through time spent on board vessels. This emphasis on sea-time has traditionally shaped career development in the maritime sector, with career progression largely based on years of experience and seniority within a given function. However, the advent of smart shipping and remote operations has created a need for hybrid competencies that span both shore-based and shipboard operations. These competencies are required for the integration of smart fleet management systems, which rely on real-time data collection and analysis, and for the operation of remote operations centers, where decisions are made based on digital information rather than direct physical observation.

The reluctance to adopt cross-functional crew development programs is indicative of a deeper cultural and organizational resistance to changing traditional career development architectures. The maritime industry's long-standing reliance on sea-time as a key determinant of career progression has led to a lack of emphasis on developing the hybrid competencies required for the digitalized maritime environment. To address this gap, shipping companies must rethink their approach to career development, moving away from rigid, sea-time-based models toward more flexible systems that accommodate the evolving nature of maritime work. This will require greater integration between shore-based and shipboard operations and the recognition that the competencies required for success in the digital age are not confined to a single domain but span across different functional areas.

One of the study's key recommendations is that future research should examine the long-term career outcomes of seafarers who participate in cross-functional development programs compared to those who follow traditional career pathways. This comparison could provide valuable insights into the effectiveness of such programs in promoting career advancement and improving overall workforce competency. Additionally, it could offer evidence on the sustainability of career trajectories for those who acquire hybrid competencies in contrast to those who continue to follow more traditional, specialized career paths. This research could help to inform the development of more effective and adaptable HRM systems that are better suited to the demands of the smart shipping era.

The study also points to the need for broader industry-wide collaboration in addressing these competency gaps. While individual shipping companies may implement training initiatives to develop the digital and cybersecurity skills of their workforce, the industry as a whole must collaborate to ensure that these efforts are systematic, standardized, and equitable. Greater cooperation between maritime training institutions, regulatory bodies, and shipping companies is essential to creating a cohesive and effective framework for competency development. This collaboration could take the form of industry-wide standards for digital and cybersecurity training, shared access to simulation resources, and the development of collaborative platforms for cross-functional crew training.

The findings of this study underscore the pressing need for comprehensive reform in maritime HRM systems to address the competency gaps created by the digitalization of shipping. The study highlights the critical importance of cybersecurity awareness and digital simulation training while also revealing the equity challenges associated with access to these resources. Moreover, it calls for a rethinking of career development models to accommodate the hybrid competencies required in the digital age. The adoption of cross-functional crew development programs and industry-wide collaboration will be key to ensuring that the global maritime workforce is adequately prepared for the challenges of smart shipping. Future research should continue to explore the long-term impacts of these changes on career trajectories and workforce development, as well as the broader implications for safety and operational efficiency in the maritime industry.

## 4. Conclusion

This study has revealed the depth and urgency of competency gaps facing the global maritime workforce in the smart shipping era, demonstrating that deficits in digital navigation proficiency, cybersecurity awareness, and remote operations collaboration represent critical threats to safe and efficient shipping operations worldwide. Through qualitative thematic analysis of thirty maritime HRM stakeholders, the research has identified four strategic HRM responses — competency-based training redesign, digital simulation integration, cross-functional crew development, and knowledge transfer systems — that collectively constitute an emerging framework for maritime workforce capability development in digital operational environments. The findings call urgently for STCW framework modernization, international cooperation on simulation infrastructure access, and organizational HRM innovation to ensure that the global seafaring workforce is equipped to navigate the smart shipping transition safely and effectively.

## References

Bilal, A., Xiao-ping, L., Nanli, Z., Sharma, R., & Jahanger, A. (2021). Green technology innovation, globalization, and CO2 emissions: Recent insights from the OBOR economies. *Sustainability, 14*(1), 236. https://doi.org/10.3390/su14010236

Caldas, P., Pedro, M. I., & Marques, R. C. (2024). An assessment of container seaport efficiency determinants. *Sustainability, 16*(11), 4427. https://doi.org/10.3390/su16114427

Caldeirinha, V., Felício, J. A., Pinho, T., & Rodrigues, R. (2024). Fuzzy-set QCA on performance and sustainability determinants of ports supporting floating offshore wind farms. *Sustainability, 16*(7), 2947. https://doi.org/10.3390/su16072947

Du, S., Zhang, H. S., & Kong, Y. (2023). Sustainability implications of the Arctic shipping route for Shanghai port logistics in the post-pandemic era. *Sustainability, 15*(22), 16017. https://doi.org/10.3390/su152216017

Jian-ping, S., Fang, C., Chen, Z., & Chen, G. (2021). Regional cooperation in marine plastic waste cleanup in the South China Sea region. *Sustainability, 13*(16), 9221. https://doi.org/10.3390/su13169221

Kim, B., Kim, G., & Kang, M.-H. (2022). Study on comparing the performance of fully automated container terminals during the COVID-19 pandemic. *Sustainability, 14*(15), 9415. https://doi.org/10.3390/su14159415

Kim, S.-K., Choi, S., & Kim, C. (2021). The framework for measuring port resilience in Korean port case. *Sustainability, 13*(21), 11883. https://doi.org/10.3390/su132111883

Liao, Y.-H., & Lee, H.-S. (2023). Using a directional distance function to measure the environmental efficiency of international liner shipping companies and assess regulatory impact. *Sustainability, 15*(4), 3821. https://doi.org/10.3390/su15043821

Mwendapole, M. J., & Jin, Z. (2021). Evaluation of seaport service quality in Tanzania: From the Dar Es Salaam seaport perspective. *Sustainability, 13*(18), 10076. https://doi.org/10.3390/su131810076

Paridaens, H., & Notteboom, T. (2021). National integrated maritime policies (IMP): Vision formulation, regional embeddedness, and institutional attributes for effective policy integration. *Sustainability, 13*(17), 9557. https://doi.org/10.3390/su13179557

Qi, J., Wang, S., & Zheng, J. (2022). Shore power deployment problem—A case study of a Chinese container shipping network. *Sustainability, 14*(11), 6928. https://doi.org/10.3390/su14116928

Yao, Y., Zheng, R., & Parmak, M. (2021). Examining the constraints on yachting tourism development in China: A qualitative study of stakeholder perceptions. *Sustainability, 13*(23), 13178. https://doi.org/10.3390/su132313178

Zhang, W., Zhang, Y., & Qiao, W. (2022). Risk scenario evaluation for intelligent ships by mapping hierarchical holographic modeling into risk filtering, ranking and management. *Sustainability, 14*(4), 2103. https://doi.org/10.3390/su14042103

Zhou, K., Yuan, X., Guo, Z., Wu, J., & Li, R. (2024). Research on sustainable port: Evaluation of green port policies on China's coasts. *Sustainability, 16*(10), 4017. https://doi.org/10.3390/su16104017

Zhu, J., Yan, W., He, J., Hafeez, M., & Sohail, S. (2024). Exploring the convergence of ICT, digital financial inclusion, environmental pressures, and free trade and their significance in driving sustainable green investment initiatives under carbon neutrality targets. *Heliyon, 10*(11), e31102. https://doi.org/10.1016/j.heliyon.2024.e31102