EPiC Series in Technology

Volume 2, 2024, Pages 16–19

Proceedings of the International Conference on
Maritime Autonomy and Remote Navigation 2023

# Human-Technology Coexistence in the Industry 4.0: The Role of Advanced Simulation Technology in Training

Gholam Reza Emad [1*], Gordon Meadow[2], and Mehrangiz Shahbakhsh[1]

[1] Australian Maritime College, University of Tasmania, Launceston, Australia

[2] SEABOT Maritime Limited, United Kingdom

Reza.emad@utas.edu.au, Gordon.meadow@seabotmaritime.com, Mehrangiz.shahbakhsh@utas.edu.au

**Abstract**

Digitalisation and autonomy, as the main drivers of the fourth industrial revolution, are transforming all industries, including the maritime industry. As the Industry 4.0 technologies such as Cyber-Physical Systems (CPS), Internet of Things (IoT), Cloud Computing, and Simulation getting mature they are transforming industries in an unprecedented way (Gilchrist, 2016; Horvat, Kroll, & Jäger, 2019; Shahbakhsh, Emad, & Cahoon, 2021; Ustundag & Cevikcan, 2017). These technologies in the context of the maritime industry have the potential to promote sustainability, enhance innovation, support education, increase efficiency, and reduce the cost of maritime operations (Emad, Khabir, & Shahbakhsh, 2020; Emad & Shahbakhsh, 2022). However, the major challenge the industry is facing is the human element (Emad, 2020a). The pace of technology progression is not the same as human adaptation in embracing these technologies where they are expected to become professional and knowledgeable users (Emad, 2020b; Emad & Ghosh, 2023). In shipping, the emergence of the autonomous ship as the outcome of Industry 4.0 implementation is influencing many aspects of the maritime industry, including its workforce (Emad, Enshaei, & Ghosh, 2021). While most maritime stakeholders are considering utilising Industry 4.0 technologies, the human element and its adaptation falls behind this revolutionary trend (Emad, 2021). As one of the most critical stakeholders, maritime operators must be upskilled and reskilled through advanced training programs to allow them to operate the advanced technologies. This is necessary for them to be able to perform the new roles and responsibilities resulting from the newly developed workplaces onboard ship and onshore. To have a better understanding of the current trend in the maritime industry and what needs to be done we performed an in-depth systematic literature review. Our research shows that to train the future workforce, among all technologies, simulation

* Corresponding author

plays a distinct role. The simulation technology as a powerful tool is not new to the industry. The earlier version of the technology was introduced by Industry 2.0 and advanced in Industry 3.0 (Gunal, 2019). However, Industry 4.0 is revolutionizing this technology and elevating its capability under Virtualisation and digital twin technology (Liljaniemi & Paavilainen, 2020; Sanchez-Gonzalez, Díaz-Gutiérrez, Leo, & Núñez-Rivas, 2019; Sánchez-Sotano, Cerezo-Narváez, Abad-Fraga, Pastor-Fernández, & Salguero-Gómez, 2020). Industry 4.0 allow the simulation to utilise other advanced technologies, such as cloud computing, mixed reality (MR), and augmented and virtual reality (AR/VR) to increase the realism of training programs and the ability to resemble real-life scenarios (Ferreira, Armellini, & De Santa-Eulalia, 2020; Rodič, 2017; Zarzuelo, Soeane, & Bermúdez, 2020). At the same time, the evolving technology-rich maritime workplaces that utilise the same technologies are providing a virtual workspace that can be perfectly simulated (Kim, Sharma, Bustgaard et al., 2021; Kumar, Arekar, & Jain; Liu, Lan, Cui et al., 2020; Sellberg, 2017). This opportunity makes the simulation/simulator the most authentic tool to train the future workforce.

**Keywords:** Industry 4.0, Simulation, Training, Autonomous shipping, Maritime workforce, Human- Technology coexistence

# 1 Aim

This research aims to investigate the importance of using technologies such as simulation in the training program of seafarers. The focus is on how this would benefit the future workforce and their readiness for the autonomous ship operations. We are especially interested to see what role the simulation technology can play in training seafarers for the transition period when the industry is shifting from traditional shipping to remotely controlled and further to autonomous shipping.

# 2 Method

To achieve the objective of this research, a systematic literature review (SRL) was conducted to analyse the existing literature in this field. The focus of the search was on the human element and the role of maritime operators in MASS and autonomous shipping. Further, the role of advanced simulation technologies for the training, upskilling, and reskilling of maritime operators was investigated.

# 3 Result

The outcome of this research shows that the role of technologies in future of ship operation with the goal to increase safety, efficiency, and security is widely explored by researchers. Moreover, the role of the earlier and current simulator/simulation technology as a training tool for proving a controlled training environment is well investigated. However, there is a lack of research on the role of advanced simulator/simulation technology in training for the current and future ships. Although the possibility of deducting the onboard training for seafarers and replacing it with simulator training has been discussed. The simulator as a predictive tool can assist the maritime industry by creating the current and future workplace environment onboard ship and onshore. It proves to be an effective tool for testing a variety of situations and scenarios and assessing the competency of maritime operators. By deploying Industry 4.0 technologies, the advanced simulators are becoming capable of designing

the current and future workplace for training the workforce. Moreover, integrating advanced simulators and digital twins can pave the way to integrating digital and real workplaces.

A simulator is a mathematical model of a workplace that can be used for depicting the design of a system and analysing the behaviour of real systems and processes. At the same time, the digital twin is a digital replica of a real workplace that feeds on real-time data to operate the physical workplace digitally. It is essential to consider that Industry 4.0 technologies aim to turn the workplace into a digital environment that is entirely different from the conventional maritime workplace. This transformation is happening through a transition period from traditional shipping to remotely controlled and finally autonomous shipping. This will have a direct effect on the seafarers/maritime operators' competencies and skills especially during the transition. Moreover, the emergence of new technologies and the advancement of existing ones create a cyber-physical workplace that promotes human-technology coexistence in the maritime industry. In this regard, to achieve the benefits of Industry 4.0 implementation in the maritime industry there is a need for all stakeholders to have a holistic approach. That entails integrating technologies in the workplace by promoting a human-centric concept in the entire transition period. This requires utilising the advanced simulation and digital twins' technology in the training program to gradually integrate the marine operators' current competency with digital and cyber knowledge and performance.

# 4 Conclusion

This research concludes with suggestions for future research agenda to foster and support the digital and advanced simulation technology in training the current and future maritime workforce. This may include:

1. Investigating the role of advanced simulator training to replace part of the onboard training of maritime operators,
2. Improving trainers' and instructors' ability in utilising the advanced simulators for training,
3. Integrating the simulator and digital twin technology in the training program,
4. Studying the psychological effect of incorporating the intelligent system into maritime workplace and its repercussion on the workforce mindset,
5. Promotion of human-centric approach that foresee the human-machine coexistence in the maritime workplace.

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