IAMU AGA26

Conference Book

26th Annual General Assembly of the International Association of Maritime Universities

Human-centred digital oceans: Educating safe & green global maritime professionals

7–10 October 2026

Split, Croatia

43°30′ N · 16°26′ E

Program Editor

Dr. Tina Perić

Vice Dean for Science

Faculty of Maritime Studies
University of Split, Croatia

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PREFACE

Welcome to the 2026 IAMU Conference

Human Centered Digital Ocean: Educating Safe & Green Global Maritime Professionals

It is my great honour, as Chair of the International Program Committee and Program Editor for the International Association of Maritime Universities (IAMU) Annual General Assembly and Conference 2026 (IAMUC 2026), to welcome you to this year's gathering of the global maritime academic community in Split, Croatia.

Hosted by the University of Split, Faculty of Maritime Studies, IAMUC 2026 brings together maritime educators, researchers, industry professionals and other stakeholders from around the world to exchange knowledge, share experience and explore the future of maritime education and training (MET). It is a particular pleasure to welcome the IAMU community to Split, a city whose identity has been shaped by the sea and whose maritime tradition continues to be closely connected with education, research and professional development.

This year's theme, "Human Centered Digital Ocean: Educating Safe & Green Global Maritime Professionals," reflects one of the most important challenges facing maritime education today: ensuring that technological transformation remains firmly centred on people. Digitalisation, automation, artificial intelligence and emerging technologies are reshaping ships, ports and maritime operations, while the transition towards safer and more environmentally sustainable shipping is creating new demands on the knowledge, skills and competencies of maritime professionals.

Against this background, IAMUC 2026 provides a valuable platform to consider not only what technologies can achieve, but also how we educate and prepare the people who will work with them. A human-centred approach requires us to place competence, safety, adaptability, ethical awareness and professional responsibility at the heart of technological and environmental transformation. The future maritime professional must be equipped not only to operate increasingly sophisticated systems, but also to understand their implications, make sound decisions and contribute meaningfully to a safer, greener and more resilient maritime sector.

The response from the international research community has been particularly encouraging. A record 214 abstracts were submitted for consideration, demonstrating the breadth of interest in the conference theme and the strength of contemporary research within the IAMU community. Following a rigorous international review process, the selected contributions presented in this

Conference Book reflect the diversity, quality and continuing development of maritime scholarship across a wide range of disciplines. The final conference programme includes 108 oral presentations across 18 technical sessions and 45 poster presentations.

The papers and presentations gathered here address many of the questions shaping the future of maritime education and the maritime industry: digital transformation and artificial intelligence, maritime safety, autonomous and smart shipping, green technologies and decarbonisation, human factors, competence development, maritime training and simulation, sustainability, and the evolving role of maritime professionals in a rapidly changing technological environment. Together, they demonstrate that innovation in maritime education is not simply about adopting new technologies, but about preparing people to use those technologies safely, responsibly and effectively.

On behalf of IAMU and the International Program Committee, I would like to express my sincere appreciation to all authors for their valuable contributions and to all reviewers for the time, expertise and commitment they devoted to the evaluation of the submissions. My gratitude also goes to the presenters and participants whose engagement, questions and discussions give life to the academic programme and strengthen the international community that IAMU represents.

I would also like to extend my deepest thanks to the University of Split, Faculty of Maritime Studies, the IAMUC 2026 Organizing Committee and the IAMU Secretariat for their dedication and support in bringing this conference to Split. Hosting the IAMU community in a city with such a strong maritime heritage is a great privilege, and we hope that the conference programme, together with the opportunities to meet and connect beyond the technical sessions, will provide an inspiring and memorable experience for all delegates.

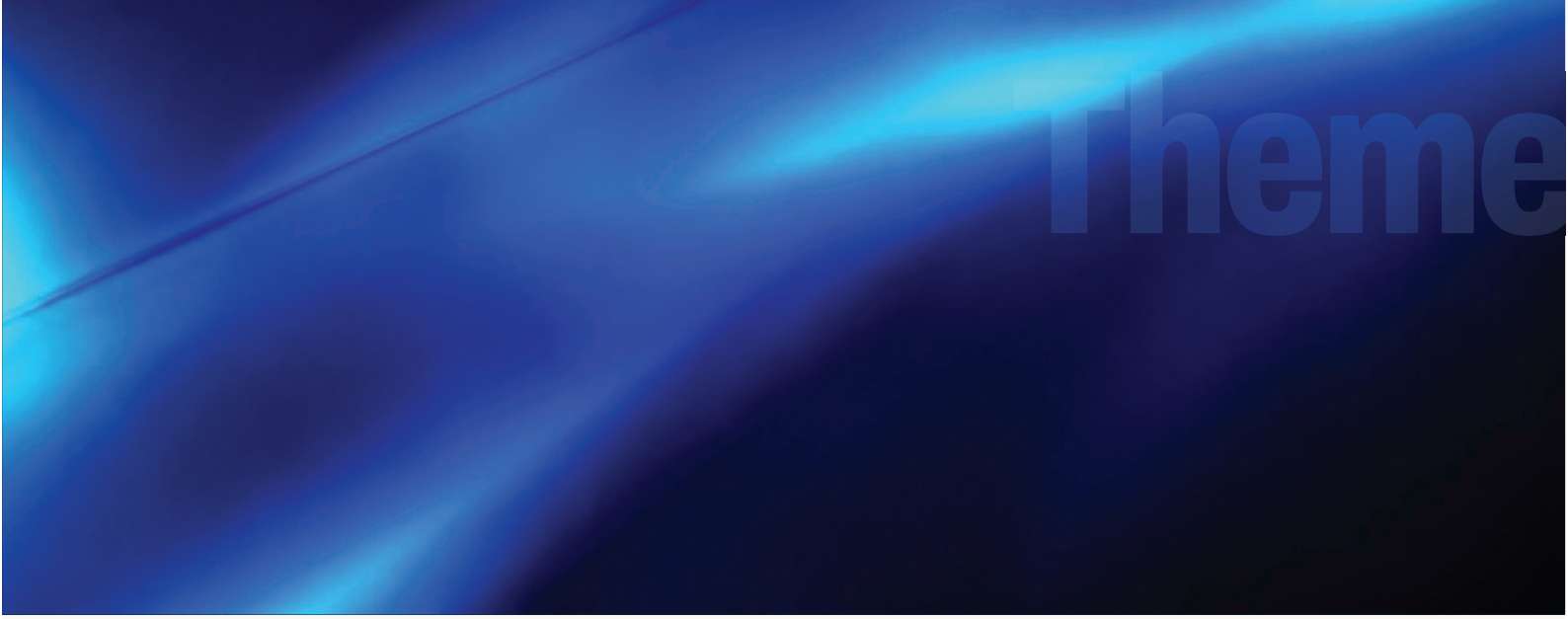
The challenges ahead of the maritime sector are significant, but so too are the opportunities. By bringing together knowledge, experience and perspectives from across the global maritime community, IAMUC 2026 contributes to a shared effort to ensure that digital and green transformation remains centred on the people who will ultimately shape its success.

I wish you an inspiring, productive and enjoyable IAMUC 2026 in Split, and I hope that the ideas and connections developed here will continue to contribute to the advancement of maritime education, research and practice long after the conference concludes.

Sincerely,

Tina Perić

Program Editor for IAMUC 2026



Main Theme

Human Centered Digital Ocean: Educating Safe & Green Global Maritime Professionals

General Theme Categories

Environmental topics

Technology Topics

Economic Topics

Social Topics

Policy Topics

Local Executive Committee (LEC)

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Dr. Chia Hsun Chang, Liverpool John Moores University, United Kingdom
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Dr. Radu Hanzu-Pazara, Constanta Maritime University, Romania
Dr. Gorana Jelić Mrčelić, Faculty of Maritime Studies, University of Split, Croatia
Dr. Emeliza T. Estimo, John B. Lacson Foundation Maritime University, Philippines

Local Programme Committee (LPC)

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Dr. sc. Nur Assani
Dr. sc. Jelena Čulić Gambiroža
Dr. sc. Matko Maleš
Dr. sc. Nikolina Pivac
Dr. sc. Toni Meštrović

Reviewers

Adamczyk Arkadiusz | Adriana Vincenca Padovan | Ahmad Moussa
Alen Jugović | Amr Moneer Ibrahim | Ana Čulić | Ana Slišković
Anamarija Stoilova | Andrea Russo | Angelica Baylon | Anita Gudelj
Avgust Panov | Biserka Rukavina | Chavdar Alexandrov | Chia-Hsun Chang
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Gregory Sholdt | Guladi Tkhilaishvili | Helena Ukić Boljat
Herbert de Vera Nalupa | Hong-Oanh Nguyen | Hrvoje Dodig | Hrvoje Karna
Igor Petrović | Igor Vujović | Ilija Knežević | Inga Bartusevičiene
Ipsita Mishra | Iryna Shvetsova | Ivan Mraković | Ivan Pavić | Ivan Peko
Ivan Pivac | Ivica Pavić | Ivo Rozić | Jakša Mišković | Jana Kegalj | Janis Kartau
Jayaprakashvel Mani | Jelena Čulić Gambiroža | Jelena Nikčević
Jelena Žanić Mikuličić | Jeric Bacasdoon | Jihwan Lee | Johan Bolmsten
Johannes Kolind | Jose Jr. Barlis | José Miguel Mahía-Prados | Josip Bašić
Jure Brčić | Kamil Formela | Kareem Tonbol | Karina Melikjanyan
Khanssa Lagdami | Krzysztof Wrobel | Ladislav Stazić | Lauri Vuoriluoto
Le Van Vang | Lea Vojković | Luka Vukić | Maciej Gucma | Maja Džoja
Maja Krčum | Mario Bakota | Marko Perkovič | Marko Zubčić | Maro Car
Martina Bašić | Mate Barić | Matthew Rooks | Merica Slišković | Miho Kristić
Mira Pavlinović | Mirko Čorić | Mišo Jurčević | Mohamed Elmeligy
Natalia Nikolova | Natalia Wagner | Nermin Hasanspahić
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Patricija Bajec | Paul Szwed | Peggy Shu-Ling Chen | Pero Vidan | Petra Amižić
Petra Bagavac | Radosław KICIŃSKI | Radu Hanzu | Rajdeep Das
Ranka Petrinović | Reza Karimpour | Rino Bošnjak | Rosanda Mulić
Samhed Rashed | Samrat Ghosh | Selen Uygur | Senka Šekularac Ivošević
Siniša Martinić-Cezar | Špiro Ivošević | Srđan Vukša | T M Rabiul Islam
Takashi Miwa | Tamari Dolidze | Tanja Brcko | Tatijana Dlabač | Tina Perić
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Vang Le Van | Vice Milin | Violeta Jurković | Vlado Frančić | Wenjun Zhang
Xinjian Wang | Yang Jeewoo | Zaloa Sanchez Varela | Zaza Shubladze
Zlatko Boko | Zorica Đurović | Zurab Bezhanovi | Zvonimir Lušić

ABOUT

IAMU and its Annual General Assembly

Founded in 1999 by seven universities from five continents, the International Association of Maritime Universities (IAMU) has developed into a global network of 83 members worldwide. Through cooperation among maritime universities, academies and other member institutions, IAMU supports the advancement of maritime education and training and promotes the exchange of knowledge, research and good practice across the international maritime community.

The Annual General Assembly (AGA) is IAMU's main annual gathering, bringing members together to exchange views, review the Association's activities and strengthen institutional cooperation. Building on the good practice of previous years, AGA26 in Split brings together several complementary formats, each serving a different purpose within the wider programme.

The Presidents' Forum creates space for university leaders to discuss strategic issues affecting IAMU and maritime higher education. The Plenary Session focuses on the formal work of the Association and matters relevant to its member institutions. IAMU project presentations provide an opportunity to share progress, results and lessons emerging from IAMU-supported initiatives. The IAMU Conference (IAMUC) complements these activities by bringing together researchers and academics to present and discuss current scientific and professional work in the maritime field.

1999
IAMU founded

7
founding universities on five continents

83
members worldwide



HOST

The host faculty

The University of Split, Faculty of Maritime Studies, is the host institution of AGA26 and IAMUC 2026. Its education and research span maritime professional practice, technology and management. As part of the University of Split, the Faculty delivers undergraduate, graduate and doctoral education and works with maritime partners on training and scientific research. Saturday's technical tour will take delegates to the University Campus and the Faculty.

Split, the host city

Split has grown around the Palace of the Roman emperor Diocletian. The palace and the historic centre form a living part of the city and have been recognised on the UNESCO World Heritage List since 1979. Hosting the opening ceremony in Diocletian's Cellars brings AGA26 into this historic setting; the rest of the programme connects the city centre with its university campus and Adriatic waterfront.

ARRIVAL AND WELCOME

Tuesday

6 October 2026

Radisson Blu Resort & Spa · Put Trstenika 19, 21000 Split

TIME	PROGRAMME	VENUE
14:00–19:00	**Early registration**	Hotel lobby registration desk
19:00–21:00	**Welcome reception** Live music **Dress guidance:** Casual – relaxed attire suitable for an outdoor BBQ.	Outdoor pool

ANNUAL GENERAL ASSEMBLY

Wednesday

7 October 2026

Diocletian's Cellars · Ul. Iza Vestibula 3, 21000 Split

Delegates travelling from the hotel should use the designated pick-up point and be there at 08:20.

TIME	PROGRAMME	VENUE
08:15	**Buses depart from the hotel pick-up point**	To Diocletian's Cellars
09:00–09:30	**Registration** For those who didn't register at the hotel lobby	Diocletian's Cellars
09:30–10:30	**AGA26 OPENING CEREMONY** Diocletian's Cellars	
	Professor Ivan Peronja Dean of the Faculty of Maritime Studies, University of Split **Jaime Veiga** Senior Project Officer, European Maritime Safety Agency **Matea Dorčić** Deputy Mayor of Split **Stipe Čogelja** Deputy Prefect of Split-Dalmatia County **Professor Nikola Koceić-Bilan** Rector of the University of Split **Professor Shan Hongjun** Chair of IAMU and President of Dalian Maritime University **Oleg Butković** Vice President of the Croatian Government, Minister of the Sea, Transport and Infrastructure	

WEDNESDAY 7 OCTOBER continued

TIME	PROGRAMME	VENUE
10:30–10:45	**Group photo** Coffee break	Peristil Diocletian's Cellars
11:00–13:00	**Presidents' Forum** Presidents or official proxies only	Hotel Cornaro
11:00–13:00	**Croatian Maritime Museum visit** 15-minute walk – meeting point: entrance at Diocletian's Cellars	Croatian Maritime Museum
13:00–14:00	**LUNCH** Diocletian's Cellars	
14:00–15:30	**Plenary Session** IAMU members only	Diocletian's Cellars
15:30–15:45	**COFFEE BREAK** Diocletian's Cellars	
15:45–17:00	**IAMU PROJECT PRESENTATIONS** Diocletian's Cellars	
15:45–15:50	**Opening of project presentations** *Christian Matthews, Head of AAC*	
15:50–16:00	**Updating STCW with rubric-based criteria for evaluation in the context of AI/GPTs – human collaborative MET learning** *Dragomir Maria-Cristina*	
16:00–16:10	**Designing Remote Pilotage using Augmented Reality Technologies** *Evelin Krmac*	
16:10–16:20	**AI-Driven Ship Recycling for Sustainable Circular Blue Economy** *Kareem Tonbol*	

WEDNESDAY 7 OCTOBER continued

TIME	PROGRAMME	VENUE
15:45–17:00	**IAMU PROJECT PRESENTATIONS, CONTINUED**	
16:20–16:30	**Innovative Seafarer Training of Risk Management for Operating Ships Using Alternative Fuels and New Technologies** *Wengang Mao*	
16:30–16:40	**Long-term Monitoring of Fishing Ships Dynamics** *Toni Llull*	
16:40–16:50	**Workforce Impact Analysis of Digitalization in Maritime Transportation** *Emre Düzenli*	
16:50–17:00	**Enhancing the Global Maritime Professional-Book of Knowledge: Development of an Integrated Cognitive-Affective-Psychomotor Learning Outcome Matrix** *Mao Tze Bayotas*	
17:00–17:05	**Closing of project presentations** *Christian Matthews, Head of AAC*	
17:00–17:15	**Greetings from the European Commissioner for Mediterranean** *Dubravka Šuica*	Diocletian's Cellars
18:15	**Buses depart from the morning drop-off point**	To MEDILS
From 18:30	**Gala dinner** Live music **Dress guidance:** Formal evening attire; please bring a warm layer for the outdoor setting.	MEDILS

IAMU CONFERENCE

Thursday

8 October 2026

Radisson Blu Resort & Spa

09:00–11:00 PARALLEL SESSIONS

PALMA ROOM	RUZMARIN ROOM	OLEANDAR ROOM
POLICY 1 Maritime Governance, Regulation, Safety and Digitalization **Facilitator: Dr. Hanzu Radu**	**TECHNOLOGY 1** Autonomous, Remote-Controlled and Intelligent Maritime Systems **Facilitator: Dr. Rino Bošnjak**	**TECHNOLOGY 2** Navigation Systems, Bridge Technology and Navigational Safety **Facilitator: Dr. Srđan Žuškin**
Peter Ivar Sandell **Salvage of Remotely Operated Autonomous Vessels – Who is entitled to Salvage Reward according to the Salvage Convention and the Law of Salvage**	*Rino Bošnjak, Filip Bojić, Mislav Maljković and Lea Vojković* **Analysis of Impact of Safety Parameters on Increased Safety Levels with Autonomous Ships**	*Miho Kristić, Nermin Hasanspahić, Tonći Biočić and Srđan Žuškin* **Quantifying COLREG Restricted Visibility: A Fuzzy Set Approach Based on Expert Maritime Judgment**
Katarzyna Skrzeszewska and Dariusz Jellonnek **Assessment of the Effectiveness of the MLC 2006 in Enforcing Seafarers' Rights in the Global and Digital Labour Market**	*Bingyu Mu, Fang Bin Guo and Zaili Yang* **VR-Constructed Scenario Mapping: A Method for Supporting Design Translation in Complex Maritime Systems**	*Ivan Mišlov, Dario Medić, Luka Grbić and Rino Bošnjak* **Integrating Eye-Tracking into Human-Centred Evaluation of Bridge Ergonomics and Navigation System Interfaces**
Xinjian Wang, Shuaibo Cheng, Wenjie Cao, Yiquan Yuan, Müge Büber and Yongqiang Zhuo **Fairness Culture in Maritime Sector: Bridging the legal and digital divides in near-miss reporting**	*João Morim, Ricardo Póvoa, Pedro Teodoro, Luís Baptisita and Bjarne Pareliussen* **Cyber-Physical Risks in Remote-Controlled Nuclear-Powered Merchant Vessels**	*Stipe Galić and Zvone Lušić* **Expert-Based Assessment of Grounding Risk in Coastal Route Selection**

09:00–11:00 PARALLEL SESSIONS

PALMA ROOM	RUZMARIN ROOM	OLEANDAR ROOM
POLICY 1 Maritime Governance, Regulation, Safety and Digitalization **Facilitator: Dr. Hanzu Radu**	**TECHNOLOGY 1** Autonomous, Remote-Controlled and Intelligent Maritime Systems **Facilitator: Dr. Rino Bošnjak**	**TECHNOLOGY 2** Navigation Systems, Bridge Technology and Navigational Safety **Facilitator: Dr. Srđan Žuškin**
Jelena Nikčević and Ivan Mraković **AtoN within the Regulatory Framework of Navigation: Evolution from Physical to Digital Navigational Solutions**	*Adithya Mahadev, Bharathi Raja Sowrirajan, Narayana Murthy Bojja and Vijay Kathirvel* **POSEIDON (Precise Oceanic Structure Engagement with Intelligent Diagnostics and Operational Networking)**	*Selahattin Alan, Elif Bal Beşikçi and Murat Selçuk Solmaz* **Assessing Human-Centered Digital Decision Support Systems in VTS Operations: A Pilot Study**
Zhen Li **From Regulatory Scoping Exercise to Governance Architecture: Reconfiguring Legal Governance of Maritime Autonomous Surface Ships in Human-Centred Digital Oceans**	*Darijo Mišković and Jakša Mišković* **Transition from Traditional Ship Control and Management towards the MASS Concept: Pros and Cons**	*Volodymyr Sikirin, Igor Vorokhobin, Dmytro Zhukov and Ruslan Kushnir* **Enhancing Data Processing Algorithms to Improve the Accuracy of Inertial Navigation Systems**
Selahattin Alan, Elif Bal Beşikçi and Michael Baldauf **Risk Factors Affecting the Interaction Dynamics Between Maritime Pilots and Tug Masters within Vessel Traffic Services**	*Peter Ivar Sandell, Lauri Vuoriluoto and Sampsa Sihvola* **Autonomous Shipping Summer School – Possibilities for Regional Co-Operation combining Companies and Universities in the Baltic Sea area**	*Dmytro Zhukov, Igor Burmaka and Bogdan Alieksieichuk* **Reducing the Impact of Navigational Accident Risks on Navigation Safety by Taking it into Account**

11:00–11:30 · COFFEE BREAK

11:30–13:30 PARALLEL SESSIONS

PALMA ROOM	RUZMARIN ROOM	OLEANDAR ROOM
ENVIRONMENTAL 1 Green Shipping, Decarbonization and Environmental Efficiency **Facilitator: Dr. Peggy Chen**	**SOCIAL 1** Seafarer Wellbeing, Mental Health and Human Factors **Facilitator: Dr. Cristina Dragomir**	**TECHNOLOGY 4** Maritime Education, Training and Digital Learning Technologies **Facilitator: Dr. Zaloa Sanchez-Varela**
Görkem Ekleme, Murat Selçuk Solmaz and Levent Erişkin **Optimization Techniques in Ship Weather Routing**	*Aman Wig, Vineesh Kumar M, Ayush Kishore Singh and D S P Vidyasagar* **Exploring Technostress on Seafarer Wellbeing: Survey Insights and Mitigation Strategies**	*Pedro Merino Laso, Florent Richard, Matthieu Sacher and Alain Martinez Laguardia* **An Open-Source, Low-Cost Navigation Console for Maritime Education and Research**
Atil Talay and Anthony Nigro **Analyzing the Impact of Speed Optimization for Reducing CO2 Emissions on Tanker Vessels**	*Ana Slišković, Ioannis Katsounis, Senka Šekularac-Ivošević and Nihan Senbursa* **Turnover Intention and Quiet Quitting among Seafarers: The Role of Demographic and Job-Related Characteristics**	*Joni Gan, Paul Olimpos and Angel Mae Gangoso* **Development of an Innovative Training Module for Automation in the Ship's Bilge Pumping System**
Filip Bojić, Ante Čalić and Kent Salo **Reducing Carbon Intensity with Methane A Questionable Solution for Maritime Decarbonisation**	*Mohab Abouelkawam, Ipsita Mishra, Shifa Shami, Pritam Pattanaik, Vik Patra and Prasheet Mishra* **Mental Fortitude at Sea: Supporting Seafarers in Crisis Zones**	*Loren Steve Glumalid, Hector Montelibano Jr. and Brian Gil Sarinas* **Development and Evaluation of a Digitalized Instruction Software for Collision Regulation Rules 13–18**
Elias Altarriba **Conceptual Influence Diagrams as a Learning Method for Understanding Climate Change Impacts on Maritime Transport**	*Tianxue Cui, Xinjian Wang and Huanxin Wang* **Unmasking the Hidden Waves of Distress: A Latent Profile Analysis of Seafarers' Anxiety and Depression**	*Murat Koray, Tamari Dolidze, Zurab Bezhanovi and Natia Vasadze* **Maritime English as a Safety Infrastructure: Towards Sustainable Communication Standards in Digital Green Oceans**
Mehdi Belabyad, Robyn Pyne, Dimitrios Paraskevadakis, Chia-Hsun Chang, Christos Kontovas and Christian Matthews **Mapping the Innovation Landscape of Green Technologies in Maritime Transportation: An Integrated Patent Analytics and Forecasting Framework**	*Andrea Russo, Sandra Bijelić-Tadić and Irena Čovo Baučić* **The Silent Side of Maritime Stress: Why Lonely Seafarers Withdraw**	*Janis Kartau* **Digital Approaches to Seafarer Certificate Renewal: Enhancing Flexibility and Objectivity in Knowledge Assessment**

11:30–13:30 PARALLEL SESSIONS

PALMA ROOM	RUZMARIN ROOM	OLEANDAR ROOM
ENVIRONMENTAL 1 Green Shipping, Decarbonization and Environmental Efficiency **Facilitator: Dr. Peggy Chen**	**SOCIAL 1** Seafarer Wellbeing, Mental Health and Human Factors **Facilitator: Dr. Cristina Dragomir**	**TECHNOLOGY 4** Maritime Education, Training and Digital Learning Technologies **Facilitator: Dr. Zaloa Sanchez-Varela**
Reza Karimpour, Luca Apicella and Emanuele Sarpero **Exploring Seafarers' Knowledge, Skill, and Proficiency on Ships' Energy-Efficient Operational Measure: Proposing Strategies Towards Shipping Decarbonization**	*Abdul Kakhidze, Avtandil Gegenava, Irakli Sharabidze, Joni Babilodze and Teimuraz Chokharadze* **Psychological Well-Being and Welfare Needs of Georgian Seafarers. A Cross-Sessional Survey Study**	*Natia Vasadze, Tamari Dolidze, Zurab Bezhanovi, Kristine Iakobadze and Teona Dzneladze* **Improving IMO SMCP and GMDSS Competence AI-Assisted Maritime English Teaching (at the example of BSMA Study)**

13:30–14:30 · LUNCH BREAK

14:30–15:00 POSTER PRESENTATIONS · BALLROOM

Miho Klaić, Srđan Vujičić, Danko Brezak and Anamarija Falkoni **Development of a Modular System for Monitoring Environmental Conditions in Shipboard and Simulation Environments**	*Nemanja Pudar, Milutin Petronijević, Ilija Knežević, Ivana Radonjić and Tatijana Dlabač* **Hardware-in-the-Loop-Based Research Framework for Renewable-Based Shipboard Power Systems**	*Paul Szwed* **Developing a Polar Shipbuilding Workforce Capacity: Job Task Analysis and Gap Analysis Informed by Global Best Practices**
Karlo Bratić, Nenad Vulić, Đorđe Dobrota and Igor Pavlović **Engine operation analysis during normal and misfire conditions**	*Filip Radunović, Zvonko Kavran, Srdjan Vujičić, Ana Krmek, Senka Šekularac Ivošević, Neven Cukrov and Špiro Ivošević* **An Innovative ROV-Assisted Method for Surface Water Microplastic Sampling in the Bay of Kotor**	*Paul Szwed* **Exploring the Use of Artificial Intelligence to Evaluate Constructive Alignment**
Brian Niels Ebdrup Rasmussen **From theory to terminal**	*Leo Stojimenov, Filip Bojić, Tino Nevešćanin and Lea Vojković* **Bridge Watch Levels and Watchkeeping Standards for Remotely Operated Vessels: Identification of Operational and Regulatory Gaps and Challenges**	*Srdjan Vujicic, Miho Klaić, Natalija Kavran, Zvonko Kavran, Špiro Ivošević, Ana Krmek, Marija Krmek and Josipa Vujević* **Development and Validation of a Harmonized Methodology for Passive Acoustic Underwater Noise Monitoring Using Marine Robotics: A Pilot Study**

14:30–15:00 POSTER PRESENTATIONS · BALLROOM

Gorana Jelić Mrčelić, Eli Marušić, Natalia Wagner, Ewa Hącia, Aleksandra Łapko and Roma Strulak-Wójcikiewicz

Sustainability Communication and Reporting by Baltic and Adriatic Ferry Operators – Implications for Future Maritime Professionals

Mehdi Belabyad, Chia-Hsun Chang, Robyn Pyne, Dimitrios Paraskevadakis, Zaili Yang, Christos Kontovas and Christian Matthews

Evolution of Remote-Control Technologies for Maritime Autonomy: A Patent-Based Technology Mapping and Forecasting Analysis

Ana Shotadze, Mzia Diasamidze, Luiza Sikharulidze and Giorgi Adamia

Geospatial Drone-Based Marine Litter Monitoring Along the Georgian Black Sea Coast: A Risk-Based Implementation Framework

Katarzyna Gaul, Sambor Guze and Artur Sylwestrzak

Navigating the competency void: Identifying shortfalls between Maritime Training and operating with Wind Assisted Propulsion Systems

Bihe Li and Wenjun Zhang

Engineering Capability-Oriented Cyber Risk Management for Intelligent Shipboard Systems: Standards, Practices, and Challenges

Jelena Žanić Mikuličić, Tomislav Skračić and Jelena Grgić

Phrasal Verbs at Sea: Why They Are Essential for Safe and Effective Communication

Cristina Dragomir

STCW – MLC Matrix for Performance. Assessing Maritime Digital Leadership for Safer and Greener Maritime Operations

Mohamed Elashwah

Human-Centered Digital Oceans: Integrating Smart Green Port Paradigms with Maritime Professional Education

Juho Hotanen and Olli-Pekka Brunila

Navigating Uncertain Futures: Digitalization, Green Transition, and Maritime Education

Doyun Chung, Chanyu Kim and Chybyung Park

Life Cycle Assessment of Electric Propulsion Ships Based on Empirical Operational Profiles

Changhai Huang, Chonglei Qi, Jian Zheng, Xucun Qi and Jingen Zhou

A physics-driven feasibility-preserving optimization framework for berth allocation and scheduling

Ilknur Colmorn, Felicia Bravo and Amin Mallek

LetsROC – Human-Centred Validation of Remote Operation Centers for Maritime Autonomous Surface Ships

Vlado Frančić, Marko Strabić, Marko Gulić and Stephen Hurd

A Proposal for Improving the Decision-Making Process for Establishing a Traffic Separation Scheme

Andrzej Stateczny, Agnieszka Lazarowska and Monika Rybczak

Intelligent Anti-collision System for Unmanned Surface Vessels Based on Short-Range 3D Automotive Radar

Igor Kozin, Lisa Loloma Froholdt, Julie Boch Waldorff, Carsten Møller, Henrik Mikkelsen, Theis Rohard, Niels Haastrup and Lars Mikkelsen

The anatomy of thermal runaway incidents in battery rooms of electric ships

Cassia Galvao and John Hark

Modernizing Maritime Education for Career-Ready Global Maritime Professionals: Bridging Curriculum, Industry, and Digital Transformation

Xiaowei Guo, Xiaoyan Xie and Wei Kang

Validation of questionnaire and passenger perceptions on QoS of access trip and port: A case study in Dalian

Bajrami Serif, Svetislav Soskic, Stefan Rasovic, Zaloa Sanchez-Varela and Milan Kresojevic

Technology and possibilities of using unmanned underwater vehicles on inland waterway

14:30–15:00 POSTER PRESENTATIONS · BALLROOM

Yuxiang Duan
Addressing cultural discount in maritime English communication: An AI-enhanced pedagogical framework

Fang Zheng, Ziaul Haque Munim, Anne Bouyssou Chen, Tae Eun Kim and William C. Gyldensten
Using Comparative Importance Improvement Analysis Method for Navigation Competence Priority Mapping

15:00–17:00 PARALLEL SESSIONS

PALMA ROOM	RUZMARIN ROOM	OLEANDAR ROOM
POLICY 2 Maritime Education, Training and Future Workforce Competence **Facilitator: Dr. Hanzu Radu**	**TECHNOLOGY 3** Human Factors, Maritime Safety and Simulator-Based Operations **Facilitator: Dr. Srđan Vujičić**	**TECHNOLOGY 5** Sustainable Shipping, Alternative Fuels and Advanced Marine Propulsion **Facilitator: Dr. Chia-Hsun Chang**
Ender Asyali, Esma Uflaz, Ozcan Arslan and Aaron Kingsbury **Designing an Industry Advisory Board for Global Maritime Education: An Action Research–Based Organizational Development Model for the IAMU**	*Srđan Vujičić, Igor Petrović, Darijo Mišković and Miho Kristić* **Observed Performance of Situational Awareness and Stress in Nautical Simulation: A Pilot Study**	*Chia-Hsun Chang, Wenming Shi, Xinjian Wang and Wonhyeong Ryu* **Bridging the Safety Gap: A Systematic Review of Maritime Education and Training Readiness for the Green Hydrogen and Ammonia**
Matthew Rooks **A Simulation-Based Training Curriculum Design for Port Radio Operators in Japan**	*Zaloa Sanchez-Varela and David Boullosa-Falces* **Human Factors in Dynamic Positioning Operations: Implications for Training and Safety**	*Anandan M, Gholam Reza Emad and Arunkumar K* **Towards Shipping Decarbonization: Experimental Assessment of Hybrid Battery-Fuel Cell Electric Propulsion System**
Eda Kefeli, Esma Uflaz and Ali Cem Kuzu **A Framework for Instructor Competency Criteria in Simulator-Based Maritime Training**	*Maro Car, David Brčić and Nermin Hasanspahić* **Investigating human factor in ECDIS-related maritime accidents: insights from investigation reports and proposals towards safety improvements**	*Minna Keinänen-Toivola, Stephen Hurd, Marko Löytökorpi, Steven E. Baer and Ashok Pandey* **Benchmarking Winter and Polar Shipping Competencies: Finland-the United States-Australia Comparison**

15:00–17:00 PARALLEL SESSIONS

PALMA ROOM	RUZMARIN ROOM	OLEANDAR ROOM
POLICY 2 Maritime Education, Training and Future Workforce Competence **Facilitator: Dr. Hanzu Radu**	**TECHNOLOGY 3** Human Factors, Maritime Safety and Simulator-Based Operations **Facilitator: Dr. Srđan Vujičić**	**TECHNOLOGY 5** Sustainable Shipping, Alternative Fuels and Advanced Marine Propulsion **Facilitator: Dr. Chia-Hsun Chang**
Oktaviani Turbaningsih, Peggy Chen, Hossein Enshaei and Mark Cooper **Workforce Development for Hydrogen Ports**	*Alen Gospic, Rino Bosnjak and Josko Soda* **Integrating Cognitive Bias into HFACS for Maritime Accident Analysis: Evidence from the Bosphorus Tanker Collision**	*Gennaro Mazzilli, Luís Filipe Baptista, Sandrina Pereira and Luis Alfonso Díaz-Secades* **A Comparative Performance Analysis of Nuclear Marine Propulsion Plants using Supercritical CO2 and Conventional Steam Cycles**
Zurab Bezhanovi, Guladi Tkhilaishvili and Givi Tsitskishvili **The Analysis of Tuning AI Tools to Bloom's Taxonomy in MET**	*Mario Musulin, Mateo Barić, Ivica Skoko and Hrvoje Nenad Musulin* **The role of navigation simulators in developing seafarers' safety competencies and reducing human error in navigation**	*José Miguel Mahía-Prados, Diogo Faustino and Sandrina Pereira* **Qualitative risk analysis on the use of SMR for maritime nuclear propulsion using HAZID and HAZOP methodologies**
Robyn Pyne, Andrew Bourton, Dimitrios Paraskevadakis and Simone Durr **Human Centred Workforce Development for Digital and Sustainable Ports**	*Lea Vojkovic, Toni Meštrović, Mario Bakota and Srđan Vukša* **Maritime Trainees' Responses to Unexpected Navigation and Technical Failures: A Simulator-Based Eye-Tracking Study**	*Anna Finamore, Claudia Antunes, Carlos Gonçalves and Jorge Antunes* **Explainable AI for Fuel-Consumption Prediction and Decarbonization KPIs Using Long-Term BOEM Operational Data**

TIME	PROGRAMME	VENUE
18:30	**Guided group walk departs from the hotel pick-up point**	**To Student Restaurant, Campus**
18:40	**Vans depart from the hotel pick-up point**	**To Student Restaurant, Campus**
From 19:00	**Dinner** Live music **Dress guidance:** Formal evening attire	**Student Restaurant, Campus**
22:30–23:00	**Return vans to Radisson Blu** Optional	**Student Restaurant, Campus**

IAMU CONFERENCE

Friday

9 October 2026

Radisson Blu Resort & Spa

09:00–11:00 PARALLEL SESSIONS

PALMA ROOM	RUZMARIN ROOM	OLEANDAR ROOM
ECONOMIC 1 Maritime Transport Economics, Efficiency and Sustainable Development **Facilitator: Dr. Eli Marušić**	**SOCIAL 2** Maritime Education, Training and Digital Transformation **Facilitator: Dr. Veli-Joel Paananen**	**TECHNOLOGY 6** Smart Ports, Maritime Logistics and Digitalization **Facilitator: Dr. Dario Medić**
Eli Marušić, Katija Kovačić, Jelena Žanić Mikuličić and Daniela Garbin Praničević **Smart and Sustainable Marinas: Digital Transformation, Digital Competencies and Organizational Performance**	*Veli-Joel Paananen, Antti Lanki and Olli-Pekka Brunila* **Beyond Standard Operating Procedures: A Framework for Simulation-Based Learning in Marine Engineering**	*Tanja Poletan Jugović, Anastazija Jakovac, Biserka Rukavina and Agata Dajčić* **The Role of Consolidator and Specifics of Consolidating LCL Cargo Flows**
Chavdar Alexandrov, Iglika Ivanova-Slavova and Nikolay Ivanov **The impact of the post-COVID world on the containerized cargo turnover in the East Mediterranean and Black Sea area**	*Luka Vukić, Yusuke Mori and Roko Glavinović* **A framework for evaluating STCW refresher training effectiveness and seafarer recovery**	*João Costa, Pedro Vítor and Ricardo Póvoa* **Fisheries Control System Regulation and Technologies**
Nanuli Charbadze and Teona Dzneladze **Economic and Technical Assessment of Modern Wind-Assisted Propulsion Systems in Maritime Cargo Transport**	*Adriana Fernandes, Valéria Magalhães Pequeno, Hugo dos Santos Marques and Anna Carolina Finamore do Couto* **Towards a Human-Centred Framework for AI-Based Maritime Training Implementation: Evidence from a PRISMA Review**	*Sophie Kircher and Katharina Renken* **How to increase the uptake of digital solutions in Container Liner Shipping: A Study Based on the Global Introduction of a Digital Berth Alignment Tool**

09:00–11:00 PARALLEL SESSIONS

PALMA ROOM	RUZMARIN ROOM	OLEANDAR ROOM
ECONOMIC 1 Maritime Transport Economics, Efficiency and Sustainable Development **Facilitator: Dr. Eli Marušić**	**SOCIAL 2** Maritime Education, Training and Digital Transformation **Facilitator: Dr. Veli-Joel Paananen**	**TECHNOLOGY 6** Smart Ports, Maritime Logistics and Digitalization **Facilitator: Dr. Dario Medić**
Weronika Ceynowa and Adam Przybyłowski **Food service quality as a human-centred operational indicator in maritime training vessels**	*Jeric Bacasdoon and Caroline Balila* **A Qualitative Analysis of Affective Learning Outcomes in Marine Transportation Curriculum**	*Mira Pavlinović, Maja Račić and Antonija Mišura* **Smart Ports in the Digital Era: The Role of Information Technologies in Enhancing Efficiency and Competitiveness**
Miiko Y. Laine, Tuulia Sillanpää and Minna M. Keinänen-Toivola **KPI Framework for Evaluating the Finnish Maritime Single Window, NEMO**	*Johan Bolmsten, Jeric Bacasdoon, Kirtan Vakil, Tirth Vakil, Claudia Barahona-Fuentes and Carolyn Graham* **A comparative study on the use of VR and actual machinery in teaching centrifugal pump operations to marine engineering students**	*Ipsita Mishra, Shifa Shami, Mohab Abouelkawam, Pritam Pattanaik, Vik Patra and Prasheet Mishra* **AI Driven Chatbot Assistance for Enhancing Port Operations and Communication Efficiency**
Olena Sienko, Sergey Karianskyi and Maryna Chesnokova **Safety-oriented Approach to Shipping Development Based on Quality Management of Technical Operation of a Vessel**	*Nicolas Nause* **Perceived knowledge growth in higher education: using students' self-reported competencies as a didactic element**	*Adriana Fernandes, Valéria Magalhães Pequeno, Hugo dos Santos Marques and Anna Carolina Finamore do Couto* **Data Governance and Data Quality Metrics in the Maritime-Port Sector: A Systematic Literature Review**

11:00–11:30 · COFFEE BREAK

11:30–13:30 PARALLEL SESSIONS

PALMA ROOM	RUZMARIN ROOM	OLEANDAR ROOM
ENVIRONMENTAL 2 Sustainable Ship Recycling, Alternative Fuels and Environmental Management **Facilitator: Dr. Peggy Chen**	**SOCIAL 3** Maritime English, Communication and Professional Competence **Facilitator: Dr. George Gabedava**	**TECHNOLOGY 7** Maritime Cybersecurity, Digital Safety and Human Reliability **Facilitator: Dr. Chia-Hsun Chang**
Eslam Gad, Khanssa Lagdami, Kareem Tonbol and Ahmed M. Ismail **An ESG-Oriented MET Framework for Safe & Green Ship Recycling Proposed under RECYCLE-SHIP Project**	*George Gabedava* **Maritime Competences for the Future: Role of Internationalization in Transversal Skills Development**	*Daisy Romanini, Marinella Petrocchi, Fabio Pinelli, Fabio Martinelli and Srđan Vujičić* **Securing the Seas: Privacy-Enhancing Technologies and Human-Machine Interaction in Maritime Cloud Environments**
Ahmed M. Ismail, Eslam Gad and Amr M. Ibrahim **Toward Safety-Centred Training Models for Alternative Fuel Ships: Human-Factors Analysis and GMP-BoK Based Guidelines for Maritime Education and Training**	*Tomislav Skracic and Jelena Žanić Mikuličić* **Interference of Croatian as the Mother Tongue among ESP students**	*Joao Morim, Joao Costa and Ricardo Povoa* **An Overview on Cybersecurity in the Maritime-Port Sector**
Muge Buber, Ali Cemal Toz, Huanxin Wang, Xinjian Wang, Xin Wang and Shengke Ni **Evaluating Emerging Technologies in Oil Spill Management Through SWOT Analysis: Insights from Multistakeholder Expert Perspectives**	*Valentyna Kudryavtseva, Svitlana Barsuk, Olena Frolova and Anca Sirbu* **A Needs-Based Upgrade of Maritime English Syllabus: Integrating Human-Related Issues**	*Rafi Ullah Khan, Christian Mathews and Zaili Yang* **Human reliability assessment in digitized maritime operations using data-driven Bayesian networks**
Ragaa Ahmed, Elen Emad and Kareem Tonbol **Human-Centered Decarbonization of Maritime Shipping: Digital Pathways Toward Safe and Green Ocean Transport**	*Alona Yurzhenko, Alona Leshchenko, Rima Mickiene and Olena Kononova* **Enhancing Maritime English Teachers' Digital Competence for Effective Online Teaching**	*Nermin Hasanspahić, Miho Kristić, Tonći Biočić and Maro Car* **Eye-Tracking in Maritime Operations: A Review of Existing Research**
Wengang Mao, Shanshan Fu and Jonas Ringsberg **Seafarer Training of Risk Management for Operating Ships Using Alternative Fuels and New Technologies**	*Maryna Chesnokova and Viktoriia Olinchuk* **Basic Principles of Professional Maritime Sociolect Formation**	*Vice Milin, Ivica Skoko, Mirko Čorić and Matko Maleš* **Ship Safety Domains: Concept Development Review**

11:30–13:30 PARALLEL SESSIONS

PALMA ROOM	RUZMARIN ROOM	OLEANDAR ROOM
ENVIRONMENTAL 2 Sustainable Ship Recycling, Alternative Fuels and Environmental Management **Facilitator: Dr. Peggy Chen**	**SOCIAL 3** Maritime English, Communication and Professional Competence **Facilitator: Dr. George Gabedava**	**TECHNOLOGY 7** Maritime Cybersecurity, Digital Safety and Human Reliability **Facilitator: Dr. Chia-Hsun Chang**
Marcella Castells-Sanabra, Clara Borén, Francesc Xavier Martínez de Osés, Leila Niyazi, Josep Ribet, Marc Vigo, Núria Pla, Sergio Velásquez, Francesc Xavier Graells, Martina Rabassa, Oriol Masdéu-Pascual and Anna Mujal-Colilles **Toward Low-Emission Port Operations: A Multidisciplinary Approach to Tugboat Emission Optimization**		*Vinka Kolić Bubić, Rino Bošnjak, Petar Bubić and Luka Grbić* **Evaluating the Implementation of S-100 Products in National Maritime Systems**

13:30–14:30 · LUNCH BREAK

14:30–15:00 POSTER PRESENTATIONS · BALLROOM

Paul Szwed and Matthew Rooks **Designing Affective Learning Pathways in Maritime Education and Training**	*Johannes Kolind* **Does anyone know what they are doing? – Surveying MET for the sustainability transitions of the maritime sector**	*Zorica Đurović and Christos Kontovas* **Has she been promoted, or at least neutralized?**
Merica Slišković, Pero Vidan, Nikola Vladimir, Danilo Nikolić, Nikolaos P. Ventikos, Srđan Vukša, Ladislav Stazić, Branko Lalić and Dario Medić **Green Maritime Corridors: A Conceptual Perspective Based on Scientific Literature**	*Kamil Formela and Pawel Kolakowski* **Rank and Experience as Determinants of Safe Passing Distance in Simulator-Based Environmental**	*Sasilatha T, Poornima B, Karthick Manoj and Neya Sridhar* **An Intelligent Hybrid CNN–ViT Framework for Sustainable Marine Species Classification in Low-Visibility Underwater Environments**
Altaf Rehman **The Sustainable Happiness Impact Index (SHII): Improving Maritime Operations Through Workforce Well-being**	*Antonio Morral, Jordi Torralbo, Toni Llull, Oriol Carrasco-Serra and Marcella Castells-Sanabra* **Energy Consumption and Environmental Impact Assessment in Bottom Trawling: Baseline Characterization and Digital On-Board Monitoring in a Commercial Trawler**	*Gregory Sholdt and Matthew Rooks* **Introducing a Collaborative Research Project for Maritime English Teachers**

14:30–15:00 POSTER PRESENTATIONS · BALLROOM

Clara Borén, Klaas de Hert, Marcella Castells-Sanabra, Cristina Campos and Joan Agut Tebé
Aligning Academic Curricula with the Digital Demands of Autonomous Maritime Transportation

Lena Granhag, Kent Salo and Annamaria Gabrielli
Sustainable shipping and environmental education for future seafarers: Reflections on teaching and learning practices

Mzia Diasamidze, Ana Shotadze and Teona Dzneladze
Academic Mobility and the Development of Human-Centered Global Maritime Professionals

Helena Ukić Boljat, Merica Slišković and Kareem Tonbol
Enhancing Sustainable Ship Recycling through Regulatory Compliance, AI, and Circular Economy Approaches

Luís Filipe Baptista, Sandrina Pereira, Aitana Sánchez-González and Luis Alfonso Díaz-Secades
Regulatory and training challenges in implementing nuclear propulsion for shipping

Sasilatha T, Salu S K and Karthick Manoj R
Multi-Granular Morphological Encoding: A Deep Learning Framework for a Sustainable Marine Biodiversity Survey

Tina Perić, Igor Pavlović, Karlo Bratić and Ivana Golub Medvešek
Types of Ship-Generated Pollution and Their Environmental Impacts: A Review with Special Reference to Nautical Tourism in Split-Dalmatia County

Dr. Sasilatha T, Neya Sridhar, Dr. Karthick Manoj R and Poornima B
GAN-Based Visual Intelligence framework for Species Identification Towards Sustainable Marine Environments

Ivan Karin, Ivana Golub Medvešek, Joško Šoda and Lucija Tadić
GIS-Based Coastal Exposure Index Derived from Ray-Fetch Geometry: A Case Study of the Pakleni Islands (Adriatic Sea)

15:00–17:00 PARALLEL SESSIONS

PALMA ROOM

POLICY 3
Sustainable Maritime Policy, Alternative Fuels and Environmental Transition
Facilitator: Dr. Hanzu Radu

Gorana Jelic Mrcelic, Eli Marusic, Maja Racic, Jelena Zanic Mikulicic, Antonija Misura and Tina Peric
Pathways to an Environmentally Sustainable Cruise Industry – What Major Cruise Companies Declare and Whether It Is Enough

Oğuz Sari and Murat Selçuk Solmaz
Training of Underwater Ship Husbandry (UWSH) Divers in Compliance with Safety Standards and Environmental (Green) Regulations: The Case of Türkiye

RUZMARIN ROOM

SOCIAL 4
Maritime Workforce, Sustainability and Human-Centred Safety
Facilitator: Dr. Minna Keinänen-Toivola

Minna M. Keinänen-Toivola, Stephen Hurd, Samrat Ghosh and Golam Reza Emad
Effectiveness and efficiency of co-operation between IAMU member universities: A SWOT analysis

Francisco Pessoa, Manuela Batista, Miguel Castro and Ângelo Cruz
Human-centred Safety Practices in the Handling of Dangerous Goods in Maritime-Port Systems

OLEANDAR ROOM

TECHNOLOGY 8
Marine Engineering, Shipboard Systems and Condition Monitoring
Facilitator: Dr. Ivan Pavić

Luka Čulić, Marko Zubčić and Ivan Pavić
Comparative Analysis of Motor Current and Stray Flux Signature Methods for Induction Motor Faults Detection in Maritime Systems

Paulo Barata and Luis Mendonça
Intelligent Incipient Fault Detection in Two-Stroke Marine Diesel Engines using Residual Indicators

15:00–17:00 PARALLEL SESSIONS

PALMA ROOM	RUZMARIN ROOM	OLEANDAR ROOM
POLICY 3 Sustainable Maritime Policy, Alternative Fuels and Environmental Transition **Facilitator: Dr. Hanzu Radu**	**SOCIAL 4** Maritime Workforce, Sustainability and Human-Centred Safety **Facilitator: Dr. Minna Keinänen-Toivola**	**TECHNOLOGY 8** Marine Engineering, Shipboard Systems and Condition Monitoring **Facilitator: Dr. Ivan Pavić**
Jihwan Lee, Jeewoo Yang, Daewon Kim, Haedong Jeon and Junhyeok Lee **Proposed Competence for Seafarers on Ships Using Non-IGF Code Alternative Fuels: Methanol, Ammonia, and Hydrogen**	*Tony Vuković, Ranka Petrinović, Roko Glavinović and Ena Sirišćević* **From Abandonment to Key Workers: The Impact of the 2014–2025 MLC Amendments on Seafarers' Labour Rights**	*Gokhan Camliyurt, Zaili Yang and Muhammet Aydin* **System-Theoretic Safety Assessment of Oil Discharge Monitoring Equipment (ODME) on Oil Tankers**
Anna Kaparaki and Christos Kontovas **Decarbonising Shipping Through Slow Steaming: Emissions, Economics and Legal Trade-offs**	*Yana Gancheva, Maryna Chesnokova and Kamelia Narleva* **Key Competencies for Sustainable Maritime Entrepreneurship**	*Madoka Miyashita, Ryoga Yamaguchi and Kentaro Tanaka* **A Study on Non-Contact Surface Tension Measurement Using Vibration Analysis of Acoustically Levitated Droplets**
Funda Yercan **Artificial Intelligence–Driven Transformation in Maritime Education and Training (MET): Institutional Governance and Competency Development in Port Operations Practices**	*Anatoli Ripalevi, Luiza Sikharulidze, Anna Shotadze and Leila Khardina* **Behavioral Dimensions of the Human Element in Maritime Cyber Resilience**	*Anita Gudelj, Merica Slišković, Helena Ukić Boljat and Ivan Buzov* **From Radar to Artificial Intelligence: Mapping Contemporary Technologies for Marine Oil Spill Detection**
Cristina Dragomir, Sanja Bauk, Angelica M. Baylon and John Tucker **STCW Assessment in the Age of GPTs - Validated Rubrics for Competency Assurance and Digital Leadership**		*Ivana Muslim, Helena Ukić Boljat and Anita Gudelj* **State of Charge Estimation for Smart Buoy Battery Systems: Classical vs. Deep Learning Approach**

FRIDAY 9 OCTOBER continued

TIME	PROGRAMME	VENUE
17:00–17:15	**IAMU AGA 2026 – Closing** **Wrap-up from the host:** Professor Ivan Peronja, Dean of the Faculty of Maritime Studies, and Željana Zovko, Member of the European Parliament, Vice-Chair of the EPP Group	Ballroom
17:15-17-20	**Passing the Hostship to IAMU AGA 27**	Ballroom
From 19:00	**Dinner at Restaurant Triton** Live music **Dress guidance:** Smart casual.	Radisson Blu Resort & Spa

TECHNICAL TOUR

Saturday

10 October 2026

University Campus and theFaculty of Maritime Studies

The technical tour takes delegates to the University Campus and the Faculty of Maritime Studies, the host institution of IAMU AGA26.

The campus brings together several faculties, the University Library and spaces for student life. Within this wider academic setting, the Faculty combines maritime education, research and professional training supported by specialist simulators. The visit offers a closer look at the environment in which future maritime professionals are educated.

Delegates may join the guided walk or take a van to the Campus.

TIME	PROGRAMME / LOGISTICS	VENUE
09:00	Guided group walk departs from the hotel pick-up point	To the Faculty of Maritime Studies
09:15	Vans depart from the hotel pick-up point	To the Faculty of Maritime Studies
12:00	Return vans to Radisson Blu	From the Faculty of Maritime Studies



Environmental Topics

Optimization Techniques in Ship Weather Routing

Görkem Ekleme [1,*], Murat Selçuk Solmaz [1] and Levent Erişkin [1]

[1] *Piri Reis University, Türkiye*
[*] *Corresponding author: gorkem03@gmail.com*

Keywords: ship weather routing; routing optimization; fuel consumption; maritime transportation

Approximately 80% of trade is conducted via maritime transport. Therefore, shipping operations are a crucial part of global trade and accordingly, reducing transportation costs is of utmost importance. In the beginning of 2023, International Maritime Organization (IMO) initiated new rating system called Energy Efficiency Existing Ship Index (EEXI) and the annual operational carbon intensity indicator (CII) index. To that end, ship weather routing is the most important step of optimizing fuel consumption and maximizing energy efficiency in terms of IMO regulations. Incorporating the decision-makers preferences into the optimization procedure, weather routing optimization algorithms also provide a valuable decision support to decision-makers.

It is aimed in this study at reviewing recent weather routing optimization studies in terms of data collection methods and optimization techniques employed. Firstly, it is focused on how relevant data required for weather routing are obtained. Then, it is surveyed different optimization algorithms used to determine optimized routings of ships under different conditions. To that end, it is compared and classified data collection methods and optimization algorithms by referring to their advantages and disadvantages. With respect to our findings, it is discussed possible research gaps within weather routing optimization. Lastly, it is proposed prospective research ideas that can be studied to fill these research gaps.

Analyzing the Impact of Speed Optimization for Reducing CO_2 Emissions on Tanker Vessels

Atil Talay [1,*] and Anthony Nigro [2]

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Keywords: Energy Efficiency Design Index (EEDI); CO_2 emissions; tanker vessels; speed optimization

Maritime transportation is responsible for the carriage of about 90% of world trade and is vital to the functioning of the global economy. The total trade volume has been increasing throughout the last century and this creates an enlargement of the world's shipping fleet, thus, increasing the amount of CO_2 emissions. According to the Green House Gas study by the International Maritime Organization (IMO), ships engaged in international trade contribute about 3% of the total world`s CO_2 emissions. In order to control CO_2 emissions from shipping, IMO has already developed some energy efficiency techniques, as well as, a global CO2 reduction index for the world, known as Energy Efficiency Design Index (EEDI). In this study, the impact of speed optimization on fuel consumption and the effect on EEDI measurements for tanker vessels were analyzed. In our analysis, the Kongsberg Full Mission Engine Room Simulator (ERS) at the United States Merchant Marine Academy (USMMA) was operated in different engine modes. Fuel consumption data was evaluated at different ship speeds and engine loads for two types of tanker vessels. Implementation of this study can be used to determine fuel consumptions and EEDI measurements at different speeds and loads between Port A and Port B. This analysis suggests that speed optimization under certain conditions is beneficial in reducing fuel consumption and in reducing CO_2 emissions, but the other effectiveness is to determine the implementation of EEDI requirements depending on the speed and load changes of tanker vessels.

Reducing Carbon Intensity with Methane: A Questionable Solution for Maritime Decarbonisation?

Filip Bojić [1,*], Ante Čalić [1] and Kent Salo [2]

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[2] *Chalmers University of Technology, Sweden*
[*] *Corresponding author: fbojic@pfst.hr*

Keywords: ship emissions; air pollution; LNG; alternative fuel; sustainable shipping

Global climate change remains one of the dominant environmental challenges, with international shipping contributing approximately 3% of total anthropogenic greenhouse gas (GHG) emissions. This share is projected to increase due to the continuous growth of maritime trade and its reliance of fossil fuels (IMO, 2020).

In response, the International Maritime Organization (IMO) introduced a series of technical and operational measures under MARPOL Annex VI, including the Energy Efficiency Design Index (EEDI), Energy Efficiency Existing Ship Index (EEXI), Ship Energy Efficiency Management Plan (SEEMP), and the operational Carbon Intensity Indicator (CII) (IMO, 2011). These mechanisms primarily aim to reduce carbon intensity by monitoring and limiting carbon dioxide (CO2) emissions generated by ships.

To comply with these regulatory requirements, the shipping sector has increasingly adopted alternative fuels, among which liquefied natural gas (LNG) has emerged as the dominant transitional solution due to its affordability and lower CO2 levels compared to conventional marine fuels. LNG is also compliant with both limitations of fuel sulphur content and limits of nitrogen oxides (NOx) (Ushakov, Stenersen and Einang, 2019). However, the increased use of LNG has also contributed to a significant rise in methane (CH4) emissions, which have shown growth of 87% in recent years (IMO, 2020).

This transformation is particularly significant since unburned CH4 has a global warming potential (GWP) 86 times greater than CO2 over a 20-year period and 28 times over a 100-year period (Shindell et al., 2013). Furthermore, existing IMO carbon-intensity measures are based solely on CO2 emissions derived from fuel consumption and therefore do not account for other pollutants including CH4 released during incomplete combustion by marine engines when operating on LNG. As a result, the environmental performance of LNG-powered vessels may be misrepresented within current regulatory frameworks.

To address stated limitations, this research analyses one year of real operational data from an LNG carrier equipped with dual-fuel diesel-electric engine (DF-DE). Initially, the vessel's Annual Efficiency Ratio (AER) and corresponding CII rating were calculated in accordance with current IMO guidelines using fuel-based method accounting CO2 only. Subsequently, methane slip emission factor, specific for case study engine, was incorporated in the calculation along with both 100-year and 20-year GWPs conversion factors. This enabled the development of adjusted carbon intensity indicators that more accurately reflect the climate impact of LNG-fueled shipping.

Preliminary results indicate that when methane slip and relevant GWPs are introduced into operational performance metrics, the calculated carbon intensity of the analyzed LNG carrier increases significantly compared to values obtained using the standard IMO methodology. These findings emphasize important methodological limitations within existing regulatory monitoring mechanisms and demonstrate the importance of integrating wider range of emission types and pollutant-specific approach into future efficiency indicators.

References

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Conceptual Influence Diagram as a Learning Method for Understanding Climate Change Impacts on Maritime Transport

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Keywords: influence diagrams; learning method; sustainable maritime transport

Achieving real sustainability in the maritime sector is a complex objective. It requires an understanding of the diverse environmental impacts of different activities to avoid situations where solving existing problems leads to the creation of new ones. There are various options for reducing greenhouse gas emissions. However, in some cases emissions may simply be shifted to another stage of the production chain. Available technologies, together with their investment and operational costs, play a significant role in ensuring economic sustainability. Changes in economic structures and practices are also necessary to achieve a socio-eco-technically sustainable system.

Due to the complexity of the maritime transport system, stakeholders often approach it based primarily on their own experiences. This kind of silo-based approach may lead to sub-optimization. One way to mitigate this is the utilization of conceptual influence diagrams (CIDs) as a collaborative learning method to improve understanding of interactions between entities in complex, interrelated systems (Carriger et al., 2018). This approach can be particularly effective in addressing management problems (Luoma et al., 2021). Influence diagrams provide a graphical representation of impacts, supporting the consideration of impact mechanisms in decision-making and facilitating stakeholder collaboration by building trust through shared understanding.

This paper presents a conceptual influence diagram developed to assess the impacts of climate change on maritime transport in the Kymenlaakso region of Finland. The influence diagram encompasses both key port operations and vessel traffic. Some elements represent direct consequences of climate-change-driven changes in prevailing weather conditions and their impact on maritime transport or port operations, including freezing and ice conditions, windiness, precipitation, heatwaves or foggy conditions. However, climate change also gives rise to numerous indirect impacts. These include, for example, political pressure to steer stakeholders towards greener solutions through legislation, which has in turn led to the introduction of new fuel and engine technologies. Such developments have significant societal implications due to the resulting need for changes in infrastructure. In addition, indirect impacts may also arise directly from direct impacts. For instance, wintertime anti-skid measures such as sanding are increasingly required in ports as temperatures fluctuate around the freezing point. These measures often lead to severe dust problems during the summer season.

The benefits of computational influence diagrams often emerge in training contexts or stakeholder collaboration, where actors frequently have limited resources to gain a holistic understanding of the system. Without such understanding, sub-optimization can lead to counterproductive outcomes. From an educational perspective, emphasis is placed on co-creating the diagram with various stakeholders. This process gives participants valuable experience in the holistic functioning of the system. Once completed, the diagram visually illustrates the system and facilitates discussion of the interactions between its components.

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Mapping the Innovation Landscape of Green Technologies in Maritime Transportation: An Integrated Patent Analytics and Forecasting Framework

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Keywords: green maritime technologies; decarbonization; patent analysis; technology diffusion; sustainable shipping

The maritime industry faces pressure to decarbonize, with the International Maritime Organization (IMO) targeting net-zero greenhouse gas emissions by 2050. This ambitious goal has pushed for rapid innovation in green maritime technologies, covering alternative fuels, energy efficiency systems, and emission reduction solutions (Bouman et al., 2017; Balcombe et al., 2019). Recent patent activity confirms accelerating technological development, with green fuel technologies showing significant convergence patterns and accounting for substantial shares of maritime innovation portfolios (Sun et al., 2024). However, despite this innovation surge, gaps remain in understanding how these diverse green technologies interconnect, which solutions demonstrate the greatest commercial potential, and how technology maturity varies across different decarbonization pathways.

This research addresses three fundamental questions: (1) What are the dominant technology clusters in maritime decarbonization innovation? (2) How do these green technologies interact and influence each other within the innovation ecosystem? (3) What are their current maturity levels and projected development trajectories toward 2050 decarbonization targets? Understanding these dynamics is essential for directing research investments, informing policy interventions, and guiding industry adoption strategies.

A comprehensive dataset of maritime green technology patents across the period 2010-2025 was collected. The search strategy includes multiple technology domains including alternative propulsion systems (LNG, methanol, ammonia, hydrogen fuel cells), energy efficiency technologies (air lubrication, wind-assisted propulsion, waste heat recovery), emission control systems (scrubbers, carbon capture), and hybrid/battery-electric propulsion (Jafarzadeh and Schjølberg, 2018; Hansson et al., 2020). The analysis goes beyong traditional patent analytics by integrating five methodological dimensions in line with Belabyad et al.(2025): (a) bibliometric analysis incorporating technology-specific citation networks and knowledge flow analysis, (b) BERTopic modeling with topic evolution tracking to capture emerging technology trends and declining legacy solutions, (c) multi-layer network analysis examining both co-occurrence and citation relationships to identify technology convergence patterns and cross-domain innovation bridges, (d) citation-augmented Bass diffusion modelling that parameterises innovation and imitation coefficients using network centrality metrics to improve forecasting accuracy, and (e) technology readiness assessment framework mapping innovations against Technology Readiness Levels (TRLs) and commercial deployment indicators.

This study's findings carry important implications for multiple stakeholder groups. For shipowners and operators, the technology maturity and integration analysis informs investment timing and technology selection strategies. For policymakers and regulatory bodies, the identification of both mature and emerging technology clusters helps calibrate incentive mechanisms and regulatory frameworks. For maritime equipment manufacturers, the network analysis shows strategic partnership opportunities and technology convergence trends. Lastly, for research institutions and funding agencies, the innovation gap analysis highlights high-priority areas requiring additional R&D investment.

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Exploring Seafarers' Knowledge, Skill, and Proficiency on Ships' Energy-Efficient Operational Measure: Proposing Strategies Towards Shipping Decarbonization

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Keywords: ship energy efficiency; operational measures; seafarers' training; maritime decarbonization

The shipping industry, responsible for nearly 3% of global greenhouse gas emissions, is a key sector in the global decarbonization agenda. Although long-term solutions such as alternative fuels and innovative ship designs remain essential, substantial near-term emission reductions can also be achieved through energy-efficient operational measures, including voyage performance management, just-in-time (JIT) arrival, weather routing, speed optimization, trim and ballast optimization, autopilot optimization, and onboard energy management systems. The effective implementation of these measures depends significantly on the knowledge, skills, and operational competencies of seafarers across both navigation and engineering departments.

This study investigates seafarers' role in improving ship energy efficiency by identifying knowledge and skill gaps related to energy-efficient operational practices. The research employed a survey-based design that combined quantitative and qualitative data collected through a structured questionnaire containing both closed-ended and open-ended questions. The questionnaire was administered to 31 seafarers, comprising 15 navigation officers and 16 marine engineers of different ranks, all with onboard experience. It examined participants' familiarity with key operational concepts, perceived challenges in implementation, and views on the adequacy of current maritime education and training.

The findings reveal uneven levels of awareness and proficiency across ranks and departments. Quantitative responses indicate variability in familiarity with JIT arrival, advanced weather routing, autopilot optimization, and waste heat recovery systems, while the open-ended responses further highlight practical barriers such as limited operational exposure, insufficient training depth, and restricted familiarity with digital support tools. These gaps were more pronounced among junior officers.

Based on these findings, the study proposes targeted, competency-based training strategies, including updated curricula, greater integration of digital operational tools, practical shipboard case-based learning, and stronger collaboration between maritime education providers and industry stakeholders. By linking seafarers' competencies with the implementation of energy-efficient operational measures, the study contributes to bridging the gap between decarbonization policy ambitions and onboard operational practice.

An ESG-Oriented MET Framework for Safe & Green Ship Recycling Proposed under RECYCLE-SHIP Project

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Keywords: ESG; maritime education and training; ship recycling; competency modelling; anti-greenwashing

Environmental, Social, and Governance (ESG) factors are increasingly shaping maritime policy and stakeholder scrutiny, and ship recycling has emerged as a critical test case because environmental, labour, and governance risks converge at the operational level. As recycling activities become more digitalised through documentation systems, data platforms, and decision-support tools, safe and green outcomes depend not only on technology but also on Maritime Education and Training (MET) that equips professionals to interpret ESG information, make decisions under uncertainty, and sustain transparent assurance processes.

Against this background, this paper proposes an ESG-oriented Maritime Education and Training (MET) framework for ship recycling, aligned with the IAMUC 2026 conference theme, Human-centred digital oceans: Educating safe & green global maritime professionals. The framework positions MET as the bridge between ship-recycling ESG expectations and the competencies needed to implement them in a digitalised operating environment.

Presented as an early conceptual dissemination output of the funded RECYCLE-SHIP project, the paper develops an education-focused design methodology that translates ship-recycling ESG issues into role-based competencies, learning outcomes, simulation-supported training activities, and quantitative prioritisation and evaluation methods. The approach integrates: (i) an ESG training needs analysis structured around ship-recycling workflows and governance expectations, including the Hong Kong Convention requirements now in force; (ii) Outcome-Based Education to formalise measurable learning outcomes for key stakeholder groups; (iii) STPA-informed socio-technical reasoning to identify ESG degradations arising from interactions among people, procedures, and connected technologies; and (iv) a calculation layer to prioritise curriculum content using a weighted ESG Competency Priority Index (ECPI) with optional fuzzy scoring.

Building on this methodology, simulation-supported exercises combine tabletop decision-making with a digital evidence dashboard and are assessed via rubric-based performance measures and a Kirkpatrick-aligned evaluation plan. The contribution is a transferable MET blueprint that links ESG pillars to ship-recycling tasks and digital control points, supports blended delivery, and provides a measurable foundation for RECYCLE-SHIP implementation and evaluation.

Toward Safety-Centred Training Models for Alternative Fuel Ships: Human-Factors Analysis and GMP-BoK Based Guidelines for Maritime Education and Training

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Keywords: human factor; alternative fuels; maritime education and training; GMP-BoK

The maritime industry's transition toward alternative marine fuels such as methanol, ammonia, and hydrogen introduces new operational hazards characterised by increased system complexity, toxicity risks, flammability, and heightened emergency response demands. While technological safeguards are rapidly advancing, the human performance dimension of alternative fuel operations remains insufficiently addressed within existing maritime education and training (MET) frameworks. Ensuring safe and sustainable implementation of green fuels, therefore, requires a structured examination of human factors and competence development.

This study investigates the human factors challenges associated with training seafarers for alternative fuel operations and evaluates how these challenges can be systematically addressed through the Global Maritime Professional Body of Knowledge (GMP-BoK). A qualitative, framework-based methodology is adopted, combining structured literature synthesis, hazard–human interaction analysis across representative operational scenarios (bunkering, routine monitoring, and emergency response), and competence mapping to GMP BoK domains.

The analysis identifies four principal categories of human-factor challenges: (1) increased cognitive workload and alarm management complexity; (2) skill gaps related to unfamiliar fuel systems and automation interfaces; (3) psychological stress and risk perception under high-consequence conditions; and (4) organisational and curriculum limitations within current training structures. These challenges are systematically mapped to relevant GMP BoK competence areas, including systems thinking, safety and risk management, human–technology interaction, leadership and decision-making, and ethical responsibility.

The findings indicate that existing minimum-competency training approaches are insufficient to meet the higher-order cognitive and behavioural demands introduced by alternative fuel technologies. The paper proposes a human-centred training model that integrates scenario-based simulation, fuel-specific emergency preparedness, and competence-based assessment, aligned with the GMP-BoK framework. By embedding structured professional knowledge domains into MET curricula, the study contributes to advancing safe, resilient, and environmentally responsible maritime operations in the era of digital and green transformation.

Evaluating Emerging Technologies in Oil Spill Management Through SWOT Analysis: Insights from Multistakeholder Expert Perspectives

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Keywords: comparative analysis; environmental sustainability; expert-based assessment; oil pollution management; oil spill response technologies; SWOT analysis

Marine oil pollution remains a critical threat to coastal ecosystems, maritime operations, and socio-economic activities, requiring more adaptive and technology-integrated response strategies. Although conventional oil spill response techniques such as mechanical recovery, dispersants, in-situ burning, sorbents, and bioremediation remain operationally important, their effectiveness is often constrained by oil weathering, met-ocean conditions, environmental sensitivity, and response time. This study evaluates conventional and emerging oil spill response technologies through a comparative and SWOT-based framework informed by multistakeholder expert perspectives. Data were obtained from 20 experts representing academics, port authority/environment representatives, maritime practitioners, direct OSR/private response firms, and environmental consultancy experts. The findings show that AI-supported monitoring, autonomous surface and underwater vehicles, advanced sorbents, magnetic nanomaterials, and hybrid response systems can improve early detection, situational awareness, operational safety, and decision-support capacity. However, high investment costs, technical complexity, limited field validation, regulatory uncertainty, training needs, and unequal technological capacity remain major barriers. Overall, the study concludes that emerging technologies should not replace conventional methods, but should complement them within hybrid, phased, and context-sensitive oil spill response systems.

Human-Centered Decarbonization of Maritime Shipping: Digital Pathways Toward Safe and Green Ocean Transport

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Keywords: decarbonization; digitalization; maritime education and training; AI; sustainable shipping

Maritime shipping carries over 80% of global trade by volume and contributes to around 3% of anthropogenic greenhouse-gas (Deng and Mi 2023). The maritime sector therefore faces a double challenge: sustaining global connectivity while rapidly aligning with climate-neutral pathways. This paper synthesizes key environmental pressures from shipping; air pollutants and GHGs, underwater noise, invasive species transfer, and marine litter and examines how human-centered digitalization can accelerate safe and green decarbonization. A structured review of more than 70 peer-reviewed studies and international reports was undertaken, including MARPOL Annex VI, the Ballast Water Management (BWM) Convention, and the 2023 Revised IMO GHG Strategy. The assessment covers CO_2, CH_4, N_2O, SO_x, NO_x and black carbon, emerging low/zero-carbon fuels (green hydrogen, ammonia and methanol), operational measures (e.g., slow steaming and route optimization), and digital tools that enhance transparency and efficiency (e.g., digital fleet-management systems and predictive analytics). Recent IMO analysis projects that, absent additional measures, total shipping GHG emissions could rise by up to 50% by 2050 relative to 2018. In contrast, scenario analyses indicate that combining low/zero-carbon fuels with digitalized operations can support progress toward IMO's 2030/2040 ambition. Delivering this transition will require substantial investment—estimated at USD 1.4–3.4 trillion by 2050—along with financing reforms and capacity building, particularly for developing and small-island states (ITF 2022). AI-enabled decision-support can strengthen energy-efficiency and maintenance planning through real-time performance management (Spandonidis et al. 2025). IoT sensors and digital twins can provide real-time data on fuel use, machinery condition, and voyage performance, enabling safer predictive maintenance and verifiable energy-efficiency improvements that support emissions-reduction compliance. Overall, we argue that decarbonization and digitalization should be treated as coupled socio-technical transitions: strengthening digital and environmental competencies among shore-based and seagoing educators is critical to scaling safe, efficient, and green shipping. Maritime education and training institutions can therefore act as frontrunners of a digitally inclusive and climate-resilient ocean economy.

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Seafarer Training of Risk Management for Operating Ships Using Alternative Fuels and New Technologies

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Keywords: net-zero emission; safety assessment; seafarer training; alternative fuels; extended reality

The shift toward alternative fuels (AFs) and new technologies (NTs) is accelerating as shipping pursues the IMO's 2050 net-zero goal. AFs such as hydrogen and ammonia bring heightened fire, explosion, and toxicity risks, while NTs like wind-assisted propulsion introduce new operational and mechanical challenges across ship handling and port activities. Although technological and environmental aspects have advanced, research on seafarer exposure, accident scenarios, and human-factor-based risk controls remains limited, hindering safe large-scale adoption. Regulatory developments highlight the urgency: the IMO Maritime Safety Committee is progressing a GHG Safety Regulatory Framework, and interim AF-training guidance exists but remains high-level and lacking integrated risk-based and human-factor analysis. Established tools such as the IMO Formal Safety Assessment and ISO risk-management standards cannot be directly applied due to novel hazard combinations, limited operational data, and complex interactions between crew, equipment, and AFs systems.

The present study develops an integrated framework to address critical safety and training challenges associated with operating ships powered by alternative fuels (AFs) and new technologies (NTs). The framework combines four methodological pillars: (1) a tailored safety assessment approach for AF/NT operations; (2) systematic identification and modelling of accident scenarios and associated risk factors; (3) quantification of human-factor influences on operational risk; and (4) the use of extended-reality (XR) bridge-simulation environments to translate risk control options (RCOs) into actionable training interventions. The safety assessment component adapts established IMO FSA and ISO risk-management principles to the unique hazard landscape of AFs and NTs, incorporating fuel-specific failure pathways, operational and human-performance uncertainties. Accident scenarios and interdependent risk-influencing factors are derived from large-scale evidence sources, including maritime accident databases and cross-industry safety analyses, and are modelled using causal logic and Bayesian techniques to produce structured AF/NT risk profiles. High-priority scenarios are subsequently transferred into XR-enabled simulator environments where operational behaviours, situational awareness demands, and human-factor error modes can be examined under controlled and repeatable conditions. These immersive simulations facilitate empirical evaluation of RCO effectiveness and support evidence-driven refinement of training interventions for hydrogen-powered and wind-assisted propulsion contexts.

The research outputs include a validated AF/NT safety-assessment methodology incorporating human-factor modelling, a set of high-risk XR simulation scenarios, and a suite of training-oriented RCOs suitable for informing future IMO HTW/MSC developments related to GHG-oriented safety regulation. Collectively, this work advances human-centred, digitally supported maritime training and contributes to safer operational pathways for decarbonized shipping.

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Toward Low-Emission Port Operations: A Multidisciplinary Approach to Tugboat Emission Optimization

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Keywords: greenhouse gas emissions; tugboats; AIS data; maritime sustainability

Maritime transport is the pillar of economic growth as it carries over 80 % of the world's trade in goods by volume (UNCTAD 2025). Among port-related vessels, tugboats play a critical operational role in ship manoeuvring but remain an under-studied emission source due to the lack of reliable methods for quantifying their highly variable in-port activities. Approaches integrating detailed operational data with emission modelling have been shown to significantly improve estimation accuracy compared with traditional bottom-up methods (Mahmud et al. 2023). The TUGEMI project (https://cremit.upc.edu/en/projectes/tugemi) introduces a comprehensive, multidisciplinary framework to characterize, quantify, and optimize tugboat emissions. The main objective is to provide insights into port operational strategies that can reduce or significantly mitigate local air pollutants from maritime activities and their harmful effects on the environment and human health. The methodology follows a structured sequence to characterize ship–tug manoeuvres in port areas by combining stakeholder interviews (Ribet et al. 2024), fuel-consumption field campaigns, emission monitoring campaigns, Automatic Identification System (AIS) data analysis (Niyazi et al. 2024), and full-mission bridge simulation. Based on the results, several operational mitigation strategies are identified: (1) optimization of free-sailing speeds through standardized speed ranges (see Figure 1); (2) improved tug allocation and port logistics planning to reduce waiting times and unnecessary transit distances (see Figure 2); (3) implementation of Engine Power Limitation (EPL) as a short-term measure, combined with the future adoption of lower-power engines while preserving safety through temporary power-boost systems; and (4) targeted training of tugboat skippers in efficient and sustainable navigation practices. This study provides a robust foundation for operational optimization, offering port authorities and tug operators evidence-based tools to reduce unnecessary engine loads, shorten waiting times, and mitigate air pollution. Improving tug manoeuvre efficiency emerges as a practical and scalable pathway toward more sustainable and lower-emission port operations.

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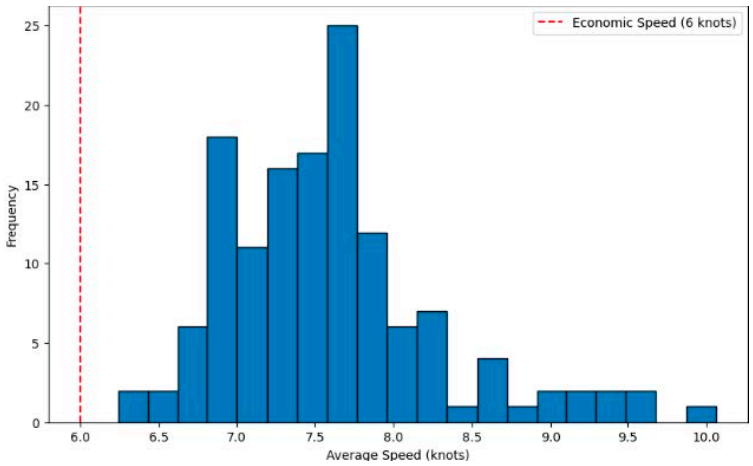


Figure 1. Average free-sailing speed distribution during tugboat shifts (year 2024)

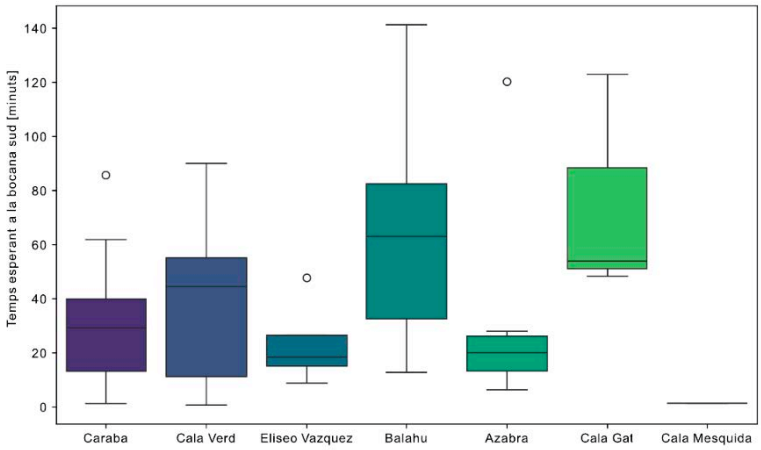


Figure 2. Waiting time (in minutes) of the tugs at the south entrance of the Port of Barcelona (data from 1/11/25-15/11/25)

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GIS-based Coastal Exposure Index Derived from Ray-fetch Geometry: A Case Study of the Pakleni Islands (Adriatic Sea)

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Keywords: coastal exposure, ray-fetch analysis, GIS, aids to navigation, Adriatic Sea

In maritime safety planning and Aids to Navigation (AtoN), there is often a lack of a simple, repeatable, and spatially explicit metric that quantifies coastal openness and exposure to the open sea. In this paper, we propose a GIS workflow based on ray–fetch analysis to compute a coastal exposure index using only landmass and coastline geometry (Dissanayake et al. 2024). At coastal points defined within a 1 km nearshore belt, 36 rays (10° angular step) are generated with a maximum range of 15 km. For each direction, the effective fetch length $L(\theta)$ is calculated to the first intersection with land or up to Lmax (Lindgren 2011). From the distribution of $L(\theta)$, we derive the metrics MeanFetch, L_{min}/L_{max}, and BlockedRatio_{1k} (the share of rays blocked within 1 km). In addition, a directional exposure index is defined as $K_{dir} = \min(1, L(\theta)/L_{ref})$, with $L_{ref} = 10$km, and then aggregated both robustly (median) and conservatively (minimum) into $K_{exposure_med}$ and $K_{exposure_min}$ (Burrows et al. 2008). The ray–fetch concept and geometric setup are illustrated in Figure 1. In a case study of the Pakleni Islands, recognizable spatial patterns were obtained: headlands and open channels show high exposure values and low blockage, whereas enclosed bays show the opposite. The proposed metric is suitable as a rapid screening layer for comparing coastal sectors and as an input to broader models for prioritizing safety measures and planning AtoN. In line with the IAMU 2026 conference theme of human-centered digital oceans, this paper addresses the limited operational use of digital environmental data in maritime safety by proposing a transparent and repeatable GIS workflow. This provides a measurable and verifiable analytical basis that supports human-centered decision-making, management, and professional education.

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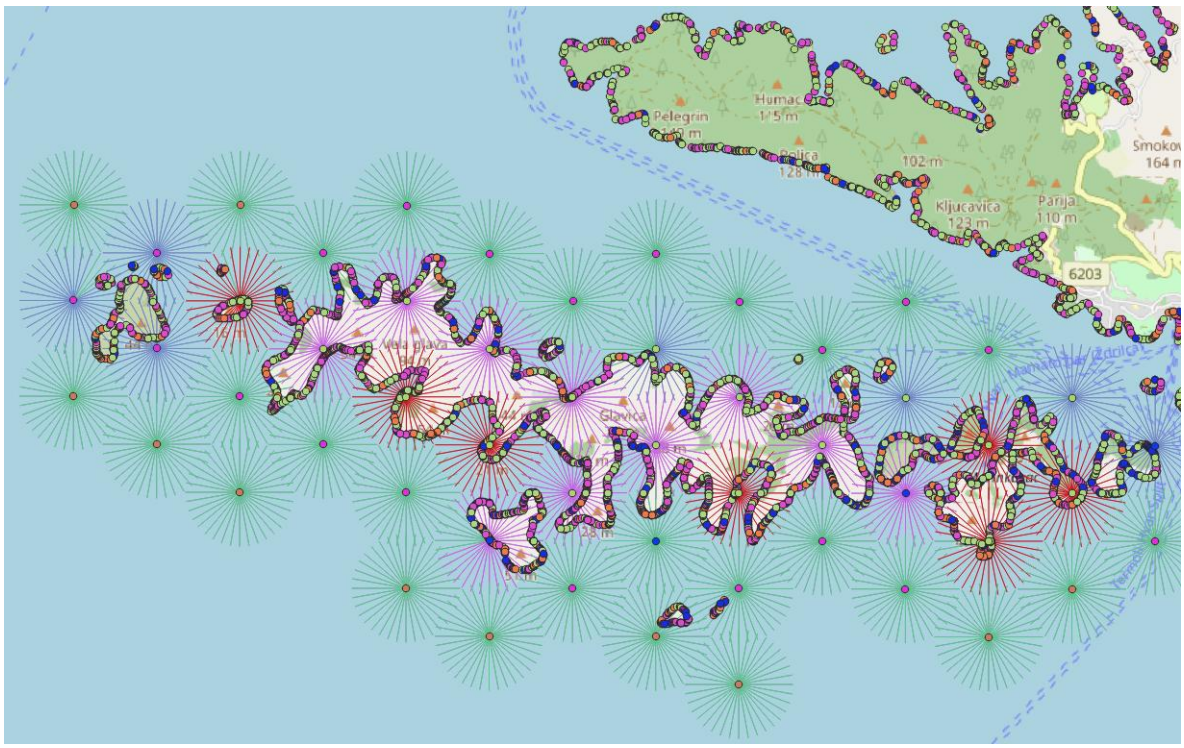


Figure 1. Ray–fetch analysis setup for the Pakleni Islands case study

Does Anyone Know What They are Doing? – Surveying MET for the Sustainability Transitions of the Maritime Sector

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Keywords: sustainability transitions; maritime education and training; MET; survey design

As of October 2025, the anticipated formal adoption of the International Maritime Organizations Net-Zero Framework was postponed for one year. Notwithstanding the resulting delay of a global fuel standard and pricing mechanism to support the transition to net zero GHG emissions by mid-century, the technological developments in cleaner fuels, battery powered vessels and related infrastructure continue (Baresic et al., 2025).

When looking solely at measures to decrease GHG emissions of the sector, reduction areas as diverse as e.g. digitalization, hydrodynamics, machinery, energy and aftertreatment listed by Vidović et al (2023) and considering the apparent regulation disparities and lack of standardization as described by Wang et al (2025) it is clear that the challenge is immense (Vidović et al., 2023; Wang et al., 2025).

Despite the lack of standardization, incentivizing pricing mechanisms, a vast technological landscape, and regulatory disparities, the international community of maritime universities and academies must be able to produce alumni with the competencies to safely and efficiently manage and operate vessels and equipment.

While recent research explores various areas to improve maritime education and training (MET) in an effort to keep pace with the technological and regulatory developments, the efforts appear scattered and focused on narrow, specific scopes (Garay-Rondero and Issa-Zadeh, 2025; Karahalios, 2025; Kim et al., 2023). To further address the knowledge gap, and as prelude to a 3-year research project to determine how to teach for the sustainability transitions of the maritime sector, this study surveys IAMU member universities to determine current and desired teaching practices. The study employs a structured, cross-sectional online survey collecting consented, anonymized responses on respondents' backgrounds, current teaching practices, infrastructure, future needs, and perceived barriers, followed by descriptive and stratified comparative analyses across roles and countries, as outlined in figure 1.

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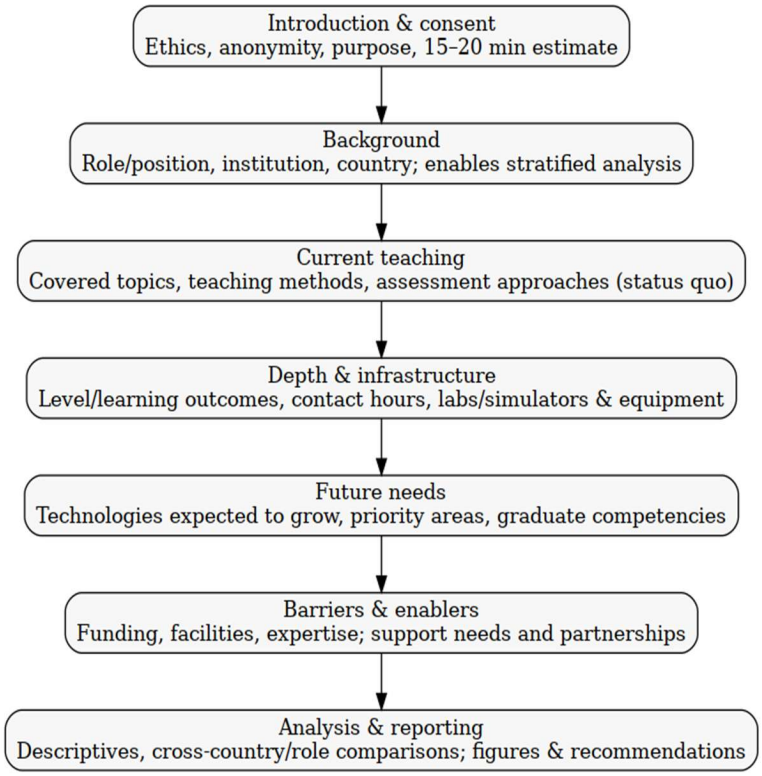


Figure 1. Methodology flow of the survey to determine current approach and desired scenario of teaching for sustainability transitions in MET

Acknowledgements

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Green Maritime Corridors: A Conceptual Perspective Based on Scientific Literature

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Keywords: green maritime corridors; maritime decarbonization; route-based approach; sustainable maritime transport; scientific literature

Reducing greenhouse gas emissions (GHG) is a global objective, and the International Maritime Organization (IMO) continually setting policy measures to facilitate reductions in maritime transport emissions. Maritime shipping still accounts for a significant share of GHG, despite being one of the most energy-efficient modes of transport. In response, new decarbonization strategies, such as green maritime corridors, are being developed. However, there is a question as to whether this concept is uniformly interpreted in scientific research. Therefore, understanding how this concept is defined and used in scientific research is essential for its successful application in policy and practice.

The aim of this paper is to analyze how the term “green maritime corridors” is described and interpreted in recent scientific literature indexed in the Web of Science database. The literature search used combinations of keywords related to green maritime corridors, and a co-occurrence analysis of titles and abstracts was used for conceptual interpretation. Additionally, annual progress reports on green shipping corridors published since 2022 were reviewed to examine their implementation in practice. The research shows that “green maritime corridors” are described in scientific literature through several interconnected themes: route-based decarbonization strategies, alternative marine fuels, port infrastructure, and policy and governance considerations. Overall, green maritime corridors are treated as integrated, route-based systems linking ports and vessels inside wider maritime decarbonization frameworks.

This study provides an understanding of green maritime corridors by examining how this relatively recent concept is addressed in scientific research and practice, and by highlighting its role in sustainable maritime transport.

Acknowledgements

This research was conducted as part of the project Green Corridors for Carbon-Neutral Cruise and Ferry Shipping in the ADRION Region (GREENROUTES), which is co-funded by the European Union through the Interreg IPA ADRION programme. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

Energy Consumption and Environmental Impact Assessment in Bottom Trawling: Baseline Characterization and Digital On-Board Monitoring in a Commercial Trawler

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Keywords: bottom trawling; energy efficiency; baseline characterization; decarbonization; maritime digitalization; high-resolution sensor monitoring

The fishing sector is increasingly challenged by international decarbonisation targets and environmental regulations, while a substantial share of coastal and Mediterranean fishing fleets continues to operate with legacy propulsion systems lacking advanced digital monitoring capabilities (IMO 2021; UNCTAD 2023). Bottom trawling is among the most energy-intensive fishing activities, primarily due to the hydrodynamic drag and benthic disturbance generated by conventional heavy steel trawl doors operating in permanent contact with the seabed (Cheilari et al. 2013).

This study presents the first phase of a comprehensive research project focused on the digital characterization and baseline energy profiling of the commercial bottom trawler Germans Maura (19.55 m LOA, 294 kW main engine), operating from the port of Llançà in the north-western Mediterranean Sea. The primary objective of this stage is to establish a high-resolution, empirical baseline model of fuel consumption, engine operational parameters, and vessel dynamics under real fishing conditions using conventional trawl gear (see Figure 1).

The methodology is based on direct, continuous monitoring using a Yacht Devices Voyage Recorder integrated with the engine management system and vessel navigation units, enabling real-time logging of fuel flow, engine speed (RPM), torque, and operational positions. Simultaneously, an Inertial Measurement Unit (IMU) with integrated GPS is deployed to capture vessel motion and dynamics, allowing the exact correlation of fuel consumption and greenhouse gas (GHG) emissions with sea states, vessel movements, and specific operational phases (navigation versus trawling).

This initial characterization phase provides a robust, empirical benchmark for the energy performance and carbon footprint (emissions per mile and per kilogram of catch) of the Mediterranean trawl fleet. Furthermore, this baseline serves as the indispensable scientific foundation for a planned future phase, in which new semi-pelagic (flying) trawl doors will be installed and instrumented with acoustic sensors. This future stage will enable a comprehensive, direct comparative assessment to accurately evaluate hydrodynamic resistance reduction, fuel savings, and seabed impact mitigation. The current results contribute directly to the EU maritime decarbonization strategies and EMFAF objectives by delivering transferable digital monitoring frameworks for artisanal and coastal fleets (European Union 2021; Generalitat de Catalunya 2022).

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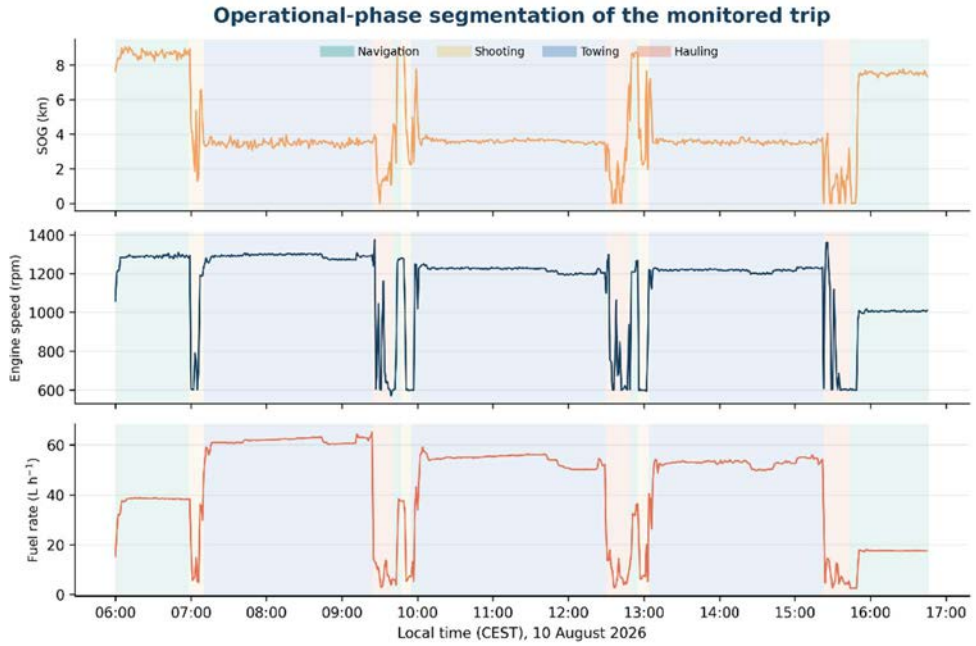


Figure 1. Example of Operational segmentation of the monitored trip on 10 August 2026. Colored backgrounds indicate phase intervals derived from the operational log; SOG, engine speed and fuel rate were used for verification.

Sustainable Shipping and Environmental Education for Future Seafarers: Reflections on Teaching and Learning Practices

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Keywords: environmental impact; sustainable shipping; integrated learning; scientific reading and writing

Shipping activities can lead to various environmental impact as release of toxic chemical substances, transfer of invasive species as well as physical disturbance of marine life. This has in recent years prompted the establishment of both global and local environmental regulations and several index for environmental performance in the shipping industry. In response, modern ships are now equipped with advanced technical systems to reduce their environmental footprint, which increases the expectations on future seafarers to have accurate and updated knowledge in environmental science and technology. To meet these expectations, it is essential that education and training in these areas are integrated early in maritime education curricula. This paper explores the challenges of teaching and learning practices implemented in a 7,5-credit 'sustainable shipping from an environmental perspective' course for second year master mariner students at Chalmers University of Technology. The course aims to provide students with a solid understanding of sustainability and environmental science, while also preparing them for the investigative writing process required in their upcoming bachelor's thesis. From this perspective, the course diverges from common STCW requirements by placing greater emphasis on abstract, higher order thinking skills such as academic writing, critical engagement with scientific literature, peer review, and oral presentation. The course is delivered in two parts, separated by an eight-week onboard training period. In the first part, students are introduced to theoretical concepts relating to environmental issues in shipping. This is followed by their onboard placement, during which the students have the opportunity to explore and apply the theories in a practical context. In the second part, students produce an argumentative or investigative report drawing on both their theoretical knowledge and their practical observations. The intended learning outcomes focus on the students' ability to scientifically and formally analyse the environmental impact of shipping, and to reflect on risk mitigation strategies and potential alternative solutions for a more sustainable maritime industry. Finally, the paper reflects on the teaching and learning of cross-curricular, transferable skills that are embedded in the course in addition to its scientific content. These include leadership, communication, and safety awareness, all essential for sustainable shipping and maritime environment.

Enhancing Sustainable Ship Recycling through Regulatory Compliance, AI, and Circular Economy Approaches

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Keywords: ship recycling; Hong Kong Convention; circular economy; Blue Economy; regulatory compliance; artificial intelligence

Ship recycling is an important aspect of maritime sustainability and plays a significant role in developing the Blue Economy through resource recovery and waste reduction. However, ship recycling practices continue to face substantial environmental, occupational safety, and regulatory challenges. Although the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships (HKC) provides a comprehensive regulatory framework, its implementation remains inconsistent, particularly in countries with high levels of ship recycling activity. This situation underscores the need for more systematic approaches to strengthen compliance and oversight mechanisms within the sector.

The RECYCLE-SHIP project addresses these challenges through an interdisciplinary research approach that combines regulatory analysis and technological perspectives within the context of sustainable ship recycling. The project examines ship recycling as a systemic issue involving governance, operational practices, and knowledge transfer across the maritime sector. India is selected as a case study due to its central position in the global ship recycling industry.

Within its defined scope, the project focuses on identifying key regulatory barriers to HKC implementation, examining the potential of AI-supported environmental and compliance monitoring to improve operational practices, developing practical circular economy strategies for the ship recycling sector, and formulating recommendations for integrating sustainable ship recycling concepts into Maritime Education and Training. By situating ship recycling within the broader context of the Circular Blue Economy, the RECYCLE-SHIP project aims to support the development of safer and more environmentally responsible recycling practices while contributing to knowledge transfer within maritime education.

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Types of Ship-Generated Pollution and Their Environmental Impacts: A Review with Special Reference to Nautical Tourism in Split-Dalmatia County

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Keywords: ship-generated pollution; nautical tourism; marine ecosystems; Split-Dalmatia County; Adriatic Sea

Maritime transport and nautical tourism constitute significant and growing sources of anthropogenic pressure on marine and coastal ecosystems. Croatia is recognised as the most popular global sailing destination; according to global yacht charter booking statistics, it accounted for more than 38% of all worldwide charter reservations in 2022. This exceptional concentration of nautical activity is particularly evident in Split-Dalmatia County, one of the principal hubs of charter operations in the Adriatic Sea and among the most intensively used nautical tourism regions in the Mediterranean. Such density of vessel traffic raises concerns regarding cumulative environmental pressures on sensitive coastal ecosystems.

This review systematically analyses the principal types of ship-generated pollution and evaluates their environmental impacts within this high-use regional context. The paper addresses marine pollution from fuel and oil spills, discharge of black and grey wastewater, atmospheric emissions, solid waste and microplastic inputs, as well as underwater noise and vibration. Particular attention is given to eutrophication processes, bioaccumulation of hazardous substances, habitat degradation, biodiversity decline, and cumulative stressors in semi-enclosed coastal systems with limited water exchange.

By synthesising existing knowledge on multiple pollution pathways within a single regional framework, this review contributes to a more comprehensive understanding of environmental pressures associated with dense nautical tourism and highlights the need for coordinated monitoring and adaptive management strategies to safeguard marine ecosystem resilience and long-term sustainability.

Acknowledgements

This study was carried out within the project *Identification of Critical Ship Traffic Areas in Nautical Tourism of Split-Dalmatia County for Environmental Protection (SeaSpot)* and was financially supported by the Faculty of Maritime Studies, University of Split.

An Innovative ROV-Assisted Method for Surface Water Microplastic Sampling in the Bay of Kotor

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Keywords: sampling; microplastic; net; remotely operated vehicle (ROV)

Microplastics are among the most persistent and dangerous marine contaminants recognized by the MARPOL Convention. Their toxicity, wide distribution, and ability to enter food chains, often mistaken by sea animals as food, can work their way up to even humans as final consumers, causing long-term environmental contamination and a threat of poisoning to their inhabitants. The Bay of Kotor was chosen as an investigation field, as a semi-enclosed marine site, suitable for high microplastic concentrations. The previous study showed that the use of a Remotely Operated Underwater Robotics (ROV) standard sampler recorded a significant amount of microplastics at microlocations within the Bay.

This study introduces a new design net and an innovative approach to microplastic sampling methodology and analysis. This innovative approach is grounded in the use of modern technologies, including ROV equipped with a new module specialised for microplastic sampling. Using the ROV-assisted innovative net, surface seawater samples were collected, suspended microplastic particles captured, and the samples transferred to the laboratory for analysis. Through filtration, separation, and isolation of suspected microplastic particles, the final identification of genuine microplastic fragments was achieved.

The results of this study, through comparative analysis, demonstrate that this innovative method is more efficient than the standard water sampling method used in previous studies by the authors. It is also expected that the innovative method will provide more reliable and representative results.

Acknowledgements

This work is supported by the project "Fostering the innovation capacities and skills for marine robotics deployment for monitoring and marine environment protection" (MARROBO), which has been approved for funding under the First Call of the Interreg VI-A IPA Program Croatia – Bosnia and Herzegovina – Montenegro 2021 – 2027, from July 15, 2024, to July 14, 2026. The MARROBO project aims to boost research and innovation in marine robotics for monitoring and protecting the marine environment. It focuses on developing advanced robotics to measure microplastics, metals in seawater, and noise pollution while building new skills. The project seeks to encourage smart investments in robotics that enhance biodiversity protection in the Adriatic Sea, reduce pollution, and promote a sustainable blue economy.

EU ETS Compliance in German Maritime SMEs: Case Study Findings and Implications for MET

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Keywords: EU ETS; FuelEU maritime; decarbonization; MET; EU allowances; carbon pricing

Since January 2024, the inclusion of shipping in the EU Emissions Trading System (EU ETS) has made climate protection a tangible and operational aspect of everyday work in the maritime industry. While regulatory compliance is rapidly becoming a core managerial task for shipping companies, maritime education and training (MET) has so far not sufficiently adapted to these changes. Current curricula remain largely focused on traditional technical competencies, safety, and watchkeeping requirements as defined by the STCW Convention, whereas environmental and regulatory competencies are still treated as supplementary rather than essential skills.

This paper examines how German maritime small and medium-sized enterprises (SMEs) are dealing with the new EU ETS requirements and discusses the implications for MET institutions and nautical students. In addition, the study addresses the evolving IMO Net-Zero Framework (IMO NZF), its interaction with the EU ETS, and the uncertainty of their harmonization, which stems from divergent geopolitical interests. Based on qualitative case studies of two German shipping companies, expert input from the German Shipowners' Association (VDR), and internal company documents, the analysis identifies emerging competence requirements related to emissions monitoring, digital reporting systems, regulatory knowledge, and the management of carbon-related costs.

Cross-case comparison of the three expert questionnaires generated a code matrix highlighting five dominant themes: regulatory experience, emissions monitoring and data processes, contracting and cost pass-through, financial exposure, and organizational resources. The pattern indicates shared structural challenges, particularly in data management, internal coordination, and financial risk handling that constrain efficient ETS and FuelEU compliance among medium-sized German shipowners.

To complement the industry perspective, a small-scale pilot survey among nautical students at a German university of applied sciences was conducted.

The goal was to find out what students thought about the decarbonization-related topics studied, what their sources of information are, and their opinion on the importance of MET institutions in adapting and improving their curriculum to better address the reduction of air pollution and GHG emissions from ships.

The nautical studies students from Jade UAS express a strong demand for earlier and more systematic integration of environmental regulation and sustainability topics into their studies, with a greater proportion believing that their own MET institution's curriculum needs to be revised. Their opinion indicates that environmental and decarbonization-related topics are currently addressed only to a limited extent within core MET subjects, with almost half of them relying on informal sources of information, such as traditional- or social-media to supplement the lack of formal academic sources.

The findings underline that environmental competence must become a core element of maritime education and professional identity. Although the EU ETS is currently a regional policy instrument, shipping operates in a global regulatory environment. Early exposure to environmental and regulatory challenges while studying at a MET institution is therefore essential to support a just transition of the maritime sector and to prepare future seafarers not only as technically competent and safety-oriented professionals, but also as environmentally responsible actors in a rapidly decarbonizing global industry.



Technology Topics

Analysis of Impact of Safety Parameters on Increased Safety Levels with Autonomous Ships

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Keywords: safety parameters; autonomous ships; levels of safety; ship collisions

The maritime industry is undergoing significant transformation driven by the development and implementation of autonomous vessels. Need for this transition is made because of ecological and economic reasons which came as result of increased ship dimensions. The purpose of autonomous ships that are unmanned or low-manned is to reduce the number of people at sea. Even if autonomous navigation does not reduce the overall number of maritime accidents, the reduction of onboard personnel exposure inherently contributes to an increase in safety at sea. Increased safety is one of the primary goals for autonomous shipping, although this safety increase has not been quantified in academic literature.

Collision avoidance is very significant factor of safety in navigation originally performed by seafarers on board. Seafarers keep a proper lookout, use navigation aids, apply COLREG rules and communicate with other approaching vessels to make an agreement regarding collision avoidance maneuver. These navigational situations are common especially in high traffic areas. This paper presents safety parameters that are essential for the advancement of navigation safety and presents how they can contribute to the improvement of autonomous navigation upgrading them in critical navigation areas.

Furthermore, the authors propose a novel model that correlates defined safety levels with the current stage of development of autonomous ship technologies and navigation systems.

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VR-Constructed Scenario Mapping: A Method for Supporting Design Translation in Complex Maritime Systems

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Keywords: human-centred design; human factors; cognitive ergonomics; user interface design; maritime operation; ship bridge

Digitalization and automation have significantly transformed vessel operating systems, enhancing efficiency and reducing physical workload while simultaneously increasing cognitive complexity for operators. Multimodal interfaces often present dense information and intricate control structures, challenging users' ability to recognize, interpret, and respond effectively. In dynamic maritime workplaces, such cognitive overload elevates mental stress, undermines well-being, and increases the likelihood of human error and operational accidents. Despite these risks, contemporary maritime system design continues to prioritise technological performance and physical ergonomics, with insufficient attention to cognitive and emotional demands.

This study argues for a paradigm shift towards Human-Centred Maritime Service Design (HCMSD) to address emerging human–machine interaction challenges in complex vessel operating environments. Drawing on prior research that identifies inadequate interface design and organisational factors as major contributors to maritime accidents, this research explores how human-centred design principles can reduce cognitive strain, minimise human error, and enhance operator performance.

Using a mixed-methods approach, the study combines a systematic literature review with a field study examining ship bridge design requirements. Behavioural mapping of Human–Machine Interaction (HMI) informs the development of ergonomic interface concepts. Design workshop outcomes, involving maritime and design experts, evaluate the effectiveness of Tangible User Interfaces (TUI) and Graphical User Interfaces (GUI) in bridge layout and interaction design. The findings demonstrate that aligning information placement with operators' mental models and real-world spatial representations can significantly reduce attentional demand and cognitive load. Ultimately, this research contributes to the development of an ideal maritime workplace that supports operator well-being, improves usability, and enhances safety and productivity through human-centred maritime service desig

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Cyber-Physical Risks in Remote-Controlled Nuclear-Powered Merchant Vessels

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Keywords: maritime cybersecurity; nuclear propulsion; remote operations; maritime education and training

Remote operations can be seen as a way to support future nuclear-powered merchant vessels operation, because not only shore-based supervision is allowed but also can reduce the number of nuclear specialists onboard (NTNU 2024; EMSA 2024). But when we move safety-critical functions closer to digital connectivity, the risk profile becomes more a cybersecurity one. If monitoring and control depends on satellite communications and remote access pathways, then reactor safety and ship integrity can be jeopardized by cyber incidents, not only by technical failures (IMO 2025; NIST 2015).

In this context, the ship should be viewed as part of a wider system. This includes not only the systems onboard, but also the remote operations centre (ROC), satellite service providers, port infrastructure, and reactor vendors. A weakness in any of these links may affect operational technology (OT) and marine control systems (MCS) onboard, and the consequences can go beyond “IT problems” and become real safety and operational issues: loss of communications leads to a loss of situational awareness and in decisions delay; manipulated data can mislead operators about the ship condition and provoke wrong decisions; unauthorised access can interfere with alarms, settings, or control functions. Moreover, research on the SatCom user segment shows that satellite dependencies cannot be treated like “trusted by default” and therefore demands layered protections and clear assumptions about threats (Casaril and Galletta 2024). In a nuclear-powered vessel context, even short period of uncertainty or degraded monitoring can increase risk and make emergency response more demanding (NTNU 2024; EMSA 2024).

In order to address this problematic, a simple cyber-physical perspective is proposed by focusing on what can realistically go wrong when remote control and remote support are part of day-to-day vessel operations. The concept idea is to look at common scenarios such as satellite link disruption, spoofed or unreliable sensor inputs, and insecure remote maintenance pathways – these topics are also discussed in wider work about autonomous and remotely operated ships (CCDCOE 2022) – and then discuss practical safeguards such as strong separation between IT and OT networks, controlled remote access, continuous monitoring, and “degraded mode” procedures that keep the ship safe when connectivity is lost or when data cannot be trusted (NIST 2015). This conceptual procedure is in line with the IMO approach, where cyber risk management should be integrated into safety management systems and supported by guidance and routines (IMO 2025).

Taking in consideration that technology development alone is not enough, it is also proposed a training approach for three personnel profiles: onboard personnel, shore-based ROC operators, and emergency situations response teams. The proposed approach is that all three groups should share a basic understanding of cyber risk, know how to recognise abnormal functional conditions, and can coordinate actions under time pressure. The proposed competencies are framed to align with STCW Convention pathways, and also to support what IMO is asking for cyber risk management, especially now that remote operations and advanced propulsion models are becoming more realistic (IMO 2025; EMSA 2024; NTNU 2024).

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POSEIDON (Precise Oceanic Structure Engagement with Intelligent Diagnostics and Operational Networking)

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Keywords: AI-integrated robotics; underwater inspection; biofouling classification; smart maintenance; affordable marine technology

The ongoing transition toward sustainable, digitally integrated maritime operations demands inspection technologies that prioritize both environmental integrity and human safety. Currently, the maritime maintenance sector faces a polarized choice: rely on high-risk, labour-intensive manual diving, or deploy capital-intensive, industrial-class Remotely Operated Vehicles (ROVs) that require specialized operational crews. There remains a critical absence of intermediate, accessible platforms capable of intelligent, real-time diagnostics rather than passive video observation. This paper presents the design, development, and active validation of POSEIDON, an ultra-low-cost, AI-driven ROV architecture engineered to bridge this gap (Figure 1). Designed with a highly modular, rapidly prototyped 3D-printed foundation, POSEIDON serves as an advanced edge-computing diagnostic platform, specifically architected to facilitate a seamless future transition from a tethered observation vehicle to a fully independent Autonomous Underwater Vehicle (AUV).

Instead of treating software and hardware as separate parts, this research treats the underwater robot as one unified system. We also developed new, low-cost mechanical designs to protect the advanced computers needed to operate in tough underwater environments. The vehicle implements a unique vector-thrusting propulsion system utilizing custom-made servos integrated into a bespoke tilt mechanism. This configuration enables full six-degree-of-freedom (6-DOF) manoeuvrability without the added weight, cost, or power consumption of traditional vertical thrusters. To ensure hydrodynamic reliability, a proprietary waterproofing methodology was engineered. This methodology utilizes in-house oil-compensated silicone-neoprene seal blend. Extensive prototype pressure-testing has successfully validated the viability of these custom actuators and seals for sustained, deep-water vector thrusting.

At the core of this research is the integration and real-world validation of three distinct artificial intelligence frameworks operating entirely at the edge. First, the system employs an AI-based visual mapping algorithm designed for autonomous underwater navigation, establishing the fundamental spatial awareness required for the platform's future AUV capabilities without need of expensive sonar modules. Second, custom computer vision models are actively being validated for the real-time detection, classification, and severity analysis of biological fouling, structural cracks, and hull dents (Figure 2). By processing these diagnostics on-board, the system eliminates the latency of post-mission video analysis and provides immediate, actionable data to operators. Third, a sophisticated sensor-fusion algorithm runs concurrently, combining continuous visual data with physical parameters from an onboard sensor suite to proactively detect and analyse invisible chemical and oil micro-leaks in the surrounding water column.

Ultimately, the system's operational superiority will be driven by the integration of a multi-layered AI architecture paired with an innovative ROV design. This advanced intelligence framework enables the vehicle to process complex, multi-modal environmental data in real-time, significantly enhancing its adaptive decision-making while laying the groundwork for future autonomous navigation. Furthermore, outfitting the vehicle with a highly responsive mechanical manipulator elevates its physical versatility. By utilizing a specialized mechanical arm with interchangeable attachments, the system can seamlessly shift between a wide variety of mission profiles—ranging from delicate biological sample collection to rigorous underwater structural maintenance—ensuring peak performance in unpredictable subsea environments.

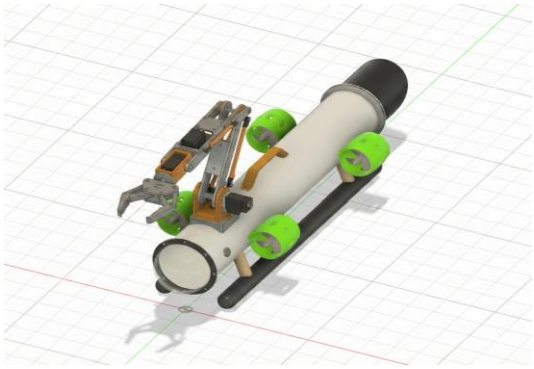


Figure 1. 3D Model of POSEIDON With Robotic Arm for underwater hull/structure maintenance.

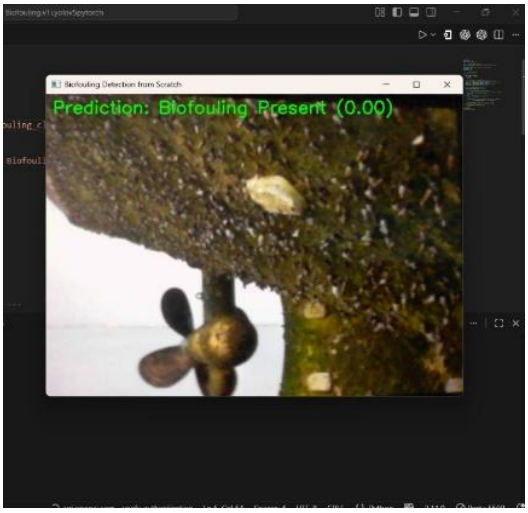


Figure 2. Biofouling/Crack/Damage detection AI Model testing.

Acknowledgements

We gratefully acknowledge the financial support provided by AMET University for the development of "Project POSEIDON." This research is supported by an institutional grant, of INR 90,000. We also thank the university administration for their continued patronage of student innovation.

Transition from Traditional Ship Control and Management towards the MASS Concept: Pros and Cons

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Keywords: autonomous shipping; seafarers; maritime safety; system reliability

The maritime industry is entering a period of profound transformation in the history of maritime operations, driven by advanced digitalization, automation, and growing societal demands for safer and greener transport. Central to this transformation is the emergence of the Maritime Autonomous Surface Ship (MASS) concept, which challenges the long-established paradigm of ship control and management based on continuous human presence on board.

Historically, maritime operations have relied on human-centered shipboard control, with navigation, engineering, and safety management performed by trained seafarers embedded within the ship's operational environment. The MASS concept introduces a gradual redistribution of control among onboard automated systems, remote shore-based operators, and ultimately artificial intelligence (AI), fundamentally altering the nature of maritime work, responsibilities, and associated risks.

This paper analyzes the transition from traditional ship control and management towards the MASS concept. In paper authors present the results of research through critically evaluation of its advantages and disadvantages not only in terms of technical capability and system design, but also through the lens of human performance, future Maritime Education and Training (MET) and seafarers' skills, maritime safety, situational awareness and system reliability.

Autonomous Shipping Summer School – Possibilities for Regional Co-Operation Combining Companies and Universities in the Baltic Sea Area

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Keywords: challenge-based learning; problem-based learning; data-driven decision-making; digitalization & AI; business intelligence (BI) & analytics

Novia Novia University of Applied Sciences has launched its first Autonomous Shipping Management Master Program for Maritime professionals' autumn 2026. A large number of the students in the programme come either from companies that have been developing autonomous maritime solutions for years or from maritime companies/authorities who will take the development forward on a practical level in companies and authority functions. Students have previously completed either a bachelor degree as sea captain, marine engineer or shipbuilding engineer or shipbuilding architecture.

For example, in several autonomous shipping projects, the Nordic maritime universities have been laying the foundation for cooperation for the use, research and teaching of autonomous vessels in schools for years. Co-operation between the Nordic countries and the countries of the Baltic Sea region has gradually deepened through various projects involving universities, authorities, maritime companies and equipment manufacturers.

Master's students are mainly working experts who seek not only new knowledge but also networking in their degree. The degree is mainly completed as distance learning and networking takes place mainly through online group work. When planning a completely new degree in the field, the work explored the possibilities of promoting networking as cost-effectively as possible so that it would be possible to bring together as many students, teachers and business experts as possible at an early stage at the start of two-year part-time studies. Since the studies can be started in August after the children's school year in Nordic countries has begun, the idea of a summer school was born, where all the actors would be brought together for a week at the end of August at the same time. For universities, this means scheduling the Master Summer School just before the start of teaching for Bachelor's degrees.

One example of cooperation with companies is the preparation of the Master Summer School, in which students jointly create practical learning assignments based on challenge- and problem-based pedagogy using simulator environments. The new pedagogical approaches are experimented together with the teachers, researchers, company representatives and students as all have a week to enjoy the challenges and problems together in cozy environment in summer-time. These workshops are partly engaging the parties for co-operation for the full period of two years studies. It is expected that this networking will lead to also changing jobs based on meetings with companies, like we have seen previously already in Master of Maritime Management Degree programme where visiting lecturers have recruited students to their companies soon after they have graduated from the programme.

The idea of a summerschool has been created by teachers making questionnaires to the students of previous Master programs. Master of maritime Management programs in Finland are for persons who at the same time are working beside their studies and represent their companies. The research has tried to measure the best possible choices for the students to have possibilities to networking in connection to studies and combine possibilities to spend enough time to effectively learn new methods of learning through simulations.

Quantifying COLREG Restricted Visibility: A Fuzzy Set Approach Based on Expert Maritime Judgment

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Keywords: risk of collision; MASS; navigation; collision avoidance

The International Regulations for Preventing Collisions at Sea (COLREG) have been corner stone of successful avoidance of collisions at sea for decades. These human-centered navigational rules, relying on good seamanship, are abundant with vague and subjective terms. Reduced visibility environment at sea, due to navigational situation uncertainty experienced by navigator, significantly elevates the risk of collision. Section III of the Rules and Rule 19. regulate conducts of vessels in the restricted visibility. Rule relies on visual observation of navigator, not on any measurable metric. Such an approach is inherently vague and subjective, which could be challenging for the development of intelligent navigational solutions. This study addresses this problem by empirically quantifying the maritime experts' interpretation of reduced visibility. The study is based on internationally conducted survey, which included significant number of active navigators, capturing their professional expertise regarding different aspects of risk of collision. To model the ambiguity of the reduced visibility term, the methodology uses fuzzy set theory. Navigational experts were asked to define ranges of five linguistic values, expressed in nautical miles, which correspond to different grades of visibility. Responses are statistically analyzed, providing a statistical data necessary for defining the range and the shape of the membership functions for each linguistic value. Furthermore, possible differences between significant groups of respondents were evaluated by analysis of variance. The survey findings provide a quantified interpretation of reduced visibility as experienced by navigational professionals: Furthermore, a fuzzy set core range where expert consensus is identified. The research demonstrates that usage of fuzzy sets is a simple and efficient tool for quantifying COLREG human-centered terms, transforming a qualitative term into a quantified, mathematically computable variables. This work contributes to maritime safety by defining a significant collision risk variable by simple and clear concept, enabling its direct applications to decision making and intelligent navigational solutions.

Integrating Eye-Tracking into Human-Centred Evaluation of Bridge Ergonomics and Navigation System Interfaces

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Keywords: competency benchmarking, environmental protection; ice navigation; Polar Code; STCW

The rapid digitalization of maritime navigation has significantly changed both ship operations and maritime education. Integrated Navigation Systems (INS), with Electronic Chart Display and Information Systems (ECDIS) at their core, now dominate bridge environments and simulator-based training As these systems become more complex, the challenge for maritime universities and training institutions is no longer limited to teaching procedural competence, but also to developing students ability to interpret digital navigation information efficiently and safely. In this context, bridge ergonomics and interface usability emerge as critical educational factors influencing situational awareness, cognitive workload, and decision-making performance.

This paper explores the use of eye-tracking technology in maritime navigation, with particular emphasis on visual attention, gaze behavior, situational awareness, human–machine interfaces, mental workload, and its potential contribution to training optimization. The simulator environment provides a safe and repeatable platform for exposing trainees to ergonomic challenges that would be difficult to isolate during real-world navigation.

The practical implications of this research are directly relevant to maritime universities and training centers. Eye-tracking findings can contribute to the development of human-centered training methodologies that align technological advancement with educational effectiveness, supporting the preparation of future officers for safe operation of modern navigation systems.

Acknowledgements

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Expert-Based Assessment of Grounding Risk in Coastal Route Selection

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Keywords: grounding risk; expert-based assessment; route selection; maritime safety

In the modern maritime industry, ship grounding remains one of the most serious safety risks, particularly in navigationally constrained areas and zones of dense traffic. This paper investigates the decision-making process in route selection while accounting for grounding risk through an expert-based assessment involving experienced masters and deck officers. Participants evaluated and ranked alternative routes differing in distance from shore, navigational complexity, spatial limitations, exposure to navigational hazards, and voyage duration, with particular emphasis placed on grounding risk assessment. The research results provide empirical support for risk-based navigation planning and contribute to the validation of quantitative grounding risk models in coastal navigation. The paper also highlights the importance of integrating professional judgement into decision-support systems aimed at improving maritime safety.

Assessing Human-Centered Digital Decision Support Systems in VTS Operations: A Pilot Study

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Keywords: VTS; digital decision support systems; situational awareness; workload; human-centered design

Digitalization in the maritime sector is playing an increasingly important role in supporting safe operations. Digital decision support systems, particularly those used in Vessel Traffic Service (VTS) operations, aim to increase operators' situational awareness and reduce human error. However, the impact of these systems on human factors needs to be evaluated from a human-centered perspective.

The study aims to examine the situational awareness, perceived workload, and trust levels in digital decision support systems among VTS operators and maritime professionals. The research utilized Endsley's three-level situational awareness model, the NASA-TLX workload scale, and the digital automation trust scale. The findings are expected to contribute to safer and more sustainable maritime operations in line with a human-centered vision of digital oceans.

A survey was carried out of actively working VTS operators. The findings indicate that digital VTS systems generally support operators' situational awareness, but in some cases, they can increase mental workload and time pressure. The study results reveal that developing digital decision support systems used in VTS operations in accordance with human-centered design principles is critical for safe and sustainable maritime operations. Furthermore, the findings indicate that digital systems in maritime education should be considered in conjunction with human factors.

Enhancing Data Processing Algorithms to Improve the Accuracy of Inertial Navigation Systems

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Keywords: maritime safety; MASS; inertial navigation system (INS); machine learning; neural network

In the context of the growing development of Maritime Autonomous Surface Ship (MASS), inertial navigation systems (INS) have become a critical component of modern navigation infrastructure, particularly in operational environments where satellite-based positioning systems such as GNSS are unavailable, degraded, or intentionally disrupted. INS provide continuous position, velocity, and attitude information independent of external signals; however, their performance is inherently limited by error accumulation caused by sensor noise, bias drift, and numerical integration processes. These errors grow over time and may significantly reduce navigation accuracy, posing risks to safe vessel operation.

This study presents a comprehensive review and analytical assessment of existing data processing and error correction techniques applied in inertial navigation systems. Particular attention is given to classical estimation methods, including Kalman filtering and its extended and adaptive variations, as well as modern adaptive filtering strategies designed to compensate for nonlinear system behavior and changing operational conditions. Additionally, recent developments in machine learning and artificial intelligence are examined, focusing on neural network-based approaches capable of identifying complex error patterns and improving prediction accuracy through data-driven learning.

Based on the identified limitations of conventional filtering methods—such as sensitivity to model uncertainties, dependence on predefined system parameters, and reduced effectiveness under highly dynamic conditions—an enhanced data processing algorithm is proposed. The suggested approach combines traditional stochastic filtering techniques with neural network learning mechanisms, enabling adaptive correction of sensor errors and improved robustness against environmental disturbances. The hybrid architecture allows real-time adjustment of model parameters and enhances long-term stability of navigation solutions.

The proposed methodology aims to improve both the accuracy and reliability of inertial navigation systems while maintaining computational efficiency suitable for onboard maritime applications. The expected outcomes demonstrate potential improvements in navigation performance, particularly during GNSS-denied operations, thereby contributing to safer autonomous vessel navigation. The research findings support ongoing efforts to enhance maritime safety and align advanced navigation technologies with the operational and regulatory requirements established by the International Maritime Organization (IMO).

Reducing the Impact of Navigational Accident Risks on Navigation Safety by Taking it into Account

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Keywords: safety of navigation; navigational risks; observation accuracy field; computer modeling

This article examines the significant factors that influence navigational safety and analyzes the feasibility and advisability of taking them into account when displaying the navigational situation. These factors include the accuracy of vessel position observation, errors arising during vessel maneuvering, and the risk of collision with hazardous targets. With the development of information technology, the display of the navigational situation has increasingly relied on technical means. With the advent of ECDIS, satellite navigation, and AIS, the use of ARPA has resulted in the synthesis and display of the navigational situation being integrated. The basic element is an electronic chart displaying the vessel's current position, as well as the positions and movement parameters of surrounding targets, both from ARPA and AIS. This method of representing the navigational situation significantly facilitates the navigator's decision-making to ensure safe navigation. However, this representation of the navigational situation is incomplete. Essential aspects affecting navigational safety, especially in areas with unreliable satellite navigation system signal reception, include the accuracy of the vessel's position, the consideration and display of vessel inertial characteristics using vessel safe zones, the overall safety assessment of the current navigation situation, the impact of external disturbances, and other aspects of navigational situation display.

Therefore, the navigational situation display model must be supplemented, first and foremost, with a visual display of the observation accuracy in the vessel's navigation area. This allows for prompt adjustment of the program trajectory to improve the accuracy of vessel position monitoring and the selection of the most favorable conditions that minimize positional errors in the vessel's observations.

In the paper: the main factors affecting navigational safety are examined, and the feasibility of taking them into account when displaying the navigational situation is demonstrated; a method for jointly accounting for the impact of navigational accident risks using an electronic chart is proposed; the results of computer simulation modeling of the vessel's observation accuracy field for several reference points are presented.

Observed Performance of Situational Awareness and Stress in Nautical Simulation: A Pilot Study

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Keywords: nautical simulator; eye tracking; situation awareness; stress

Although situational awareness and stress management are important for safe maritime navigation, there is little research using objective technological methods to study how senior naval officers develop situational awareness and experience stress when assuming command. There is a particular lack of research on highly certified officers in realistic but controlled conditions on the navigation bridge. Therefore, pilot studies using tools such as eye tracking and stress analysis are needed. The aim of this pilot study was to examine differences in participants perceived overall performance, with a particular focus on situational awareness and stress. The study involved six participants with the highest maritime certifications, Chief Officer and/or Ship Master. All participants were familiar with the bridge equipment and environment and provided informed consent to participate and use the eye tracking device before the experiment. In the experimental scenario, the officer of the watch (OOW) initially directed the ship's navigation, while the participant in the role of master observed his work. After gathering the necessary information and developing situational awareness, the participant took over the navigational watch and continued to steer the ship. To ensure that the initial conditions were the same for all participants, the officer of the watch always acted in the same way during the initial phase, regardless of the participants' reactions, until formally relieved. During the exercise, data were collected on the participants' gaze direction towards predefined areas of interest, bridge communication, and their behavior and reactions. After completing the exercise, the participants assessed their own stress levels. The results of this pilot study indicate the need for further research, especially in the area of stress assessment using advanced technological methods, which will be further developed within the MASTERS project.

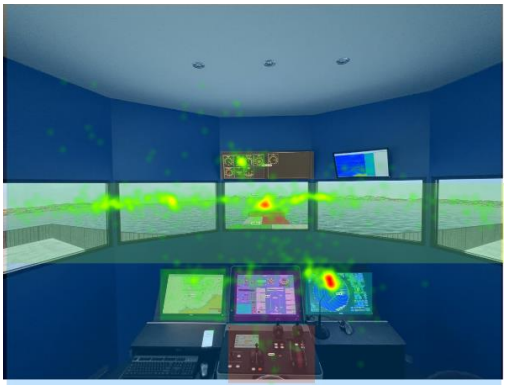
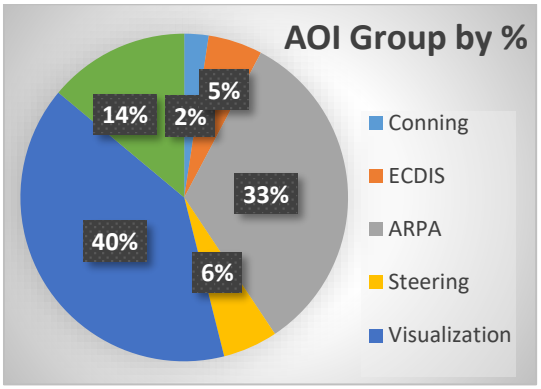


Figure 1: Eye tracking heat map, Respondent 1



Graph 1: Percentage according AOI

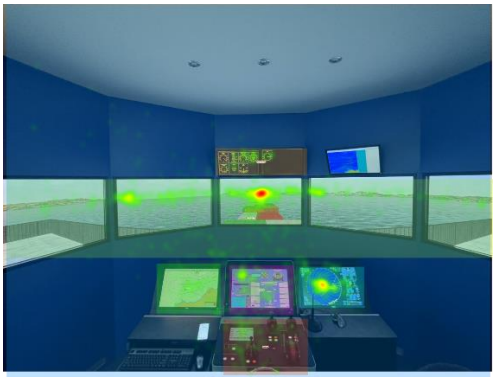
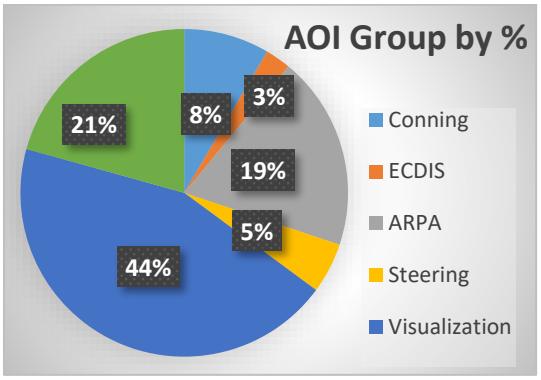


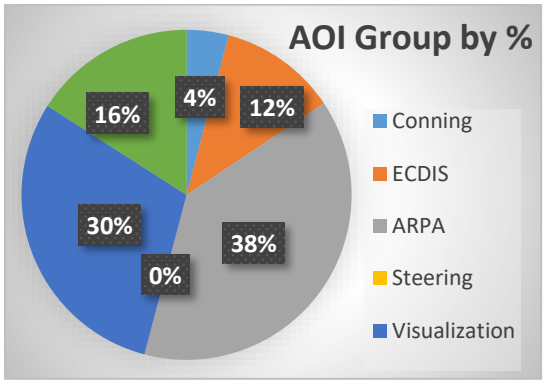
Figure 2: Eye tracking heat map, Respondent 2



Graph 2: Percentage according AOI



Figure 3: Eye tracking heat map, Respondent 3



Graph 3: Percentage according AOI

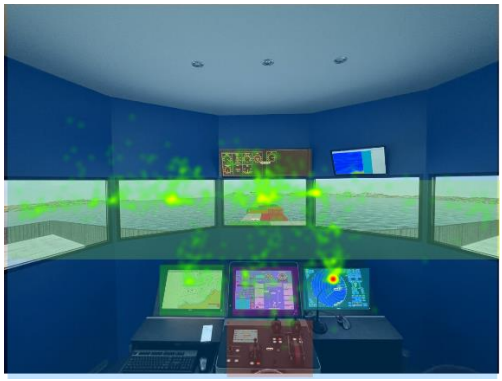
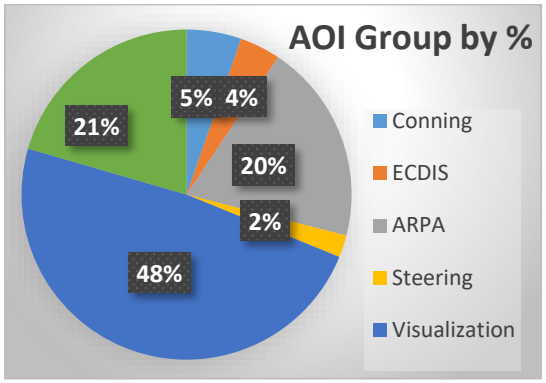


Figure 4: Eye tracking heat map, Respondent 4



Graph 4: Percentage according AOI

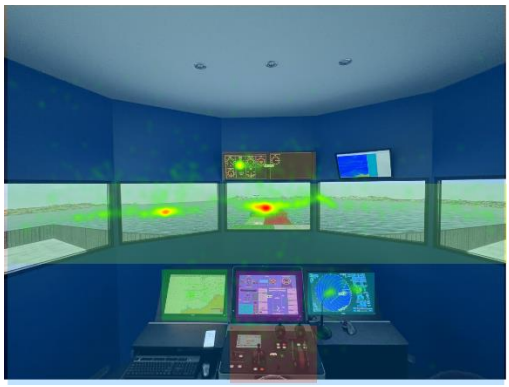
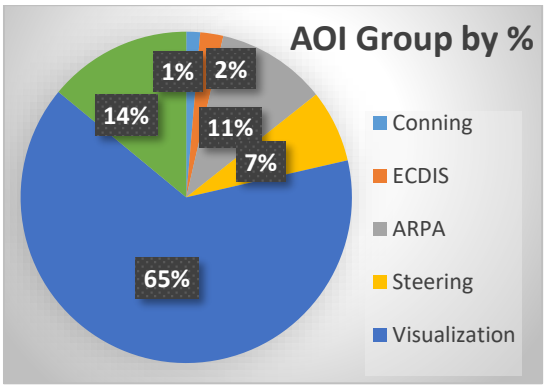


Figure 5: Eye tracking heat map, Respondent 5



Graph 5: Percentage according AOI

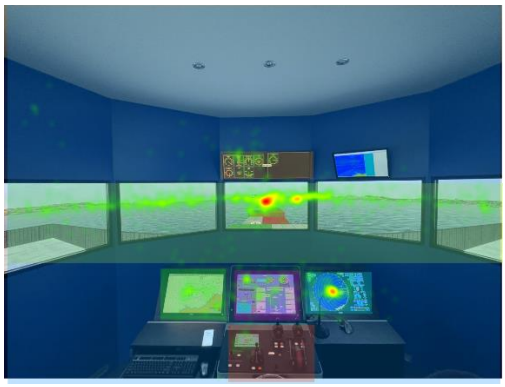
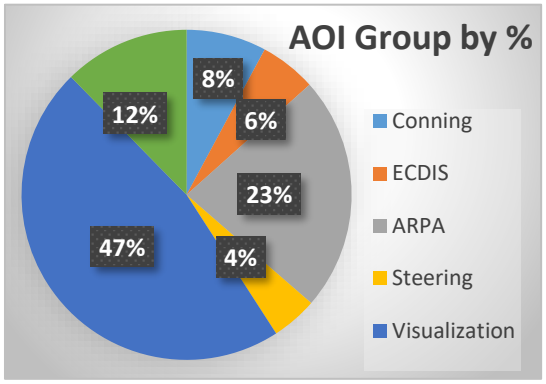


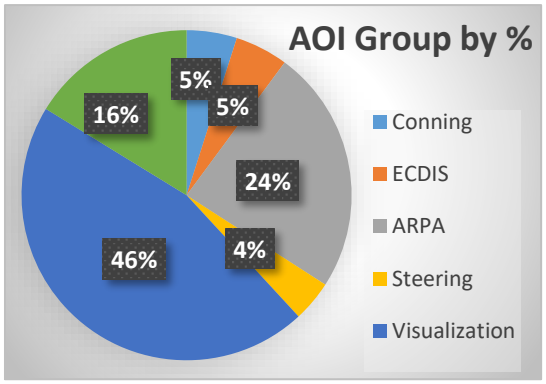
Figure 6: Eye tracking heat map, Respondent 6



Graph 6: Percentage according AOI



Figure 7: Eye tracking heat map, Summary



Graph 7: Percentage according AOI

AREA OF INTEREST	CONNING	ECDIS	ARPA	STEERING	VISUALISATION	TOTAL OUTSIDE
1ST RESPONDENT AD	2.40%	5.36%	32.90%	5.42%	39.99%	13.94%
2ND RESPONDENT AZ	8.46%	2.52%	19.16%	4.97%	44.21%	20.69%
3RD RESPONDENT MD	4.12%	11.52%	38.46%	0.01%	29.93%	15.95%
4TH RESPONDENT MC	5.37%	4.00%	19.63%	2.17%	48.32%	20.51%
5TH RESPONDENT NG	1.35%	2.25%	10.74%	7.07%	64.57%	14.02%
6TH RESPONDENT DM	7.85%	5.53%	23.00%	4.49%	46.78%	12.35%
MEAN (AVERAGE)	4.93%	5.20%	23.98%	4.02%	45.63%	16.24%
MIN	1.35%	2.25%	10.74%	0.01%	29.93%	12.35%
MAX	8.46%	11.52%	38.46%	7.07%	64.57%	20.69%

Acknowledgements

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Human Factors in Dynamic Positioning Operations: Implications for Training and Safety

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Keywords: dynamic positioning; human error; maritime safety; risk modelling; maritime education

Dynamic Positioning (DP) drilling operations are widely recognised as high-risk maritime activities. Even with increasingly sophisticated DP systems and well-defined procedures, incidents continue to occur, and human error remains a recurring factor. Several probabilistic approaches have been proposed to estimate the likelihood of such incidents, but there is still limited evidence on how well these models hold up over time, particularly as technology, training practices, and operational contexts evolve.

This paper examines human-error-related incidents in DP drilling operations using an independent dataset covering the period from 2016 to 2024. The analysis applies an existing human-error likelihood model to recent operational data and compares the predicted incident likelihoods with what was actually observed. Attention is given to changes over time and to whether the model remains stable under conditions of increased digitalisation, revised competence requirements, and ongoing development of DP training and operational practices.

The preliminary results suggest that the general structure of the model continues to be applicable across the analysed period. However, differences emerge in the contribution of specific human-factor elements. Some contributors appear to change more noticeably over time, indicating that certain aspects of human error may be more sensitive to training approaches and operational context than others. This points to the inherently adaptive nature of human performance in complex DP operations.

Alongside model validation, the paper considers what these findings mean for maritime education and training. The results help distinguish between human-error mechanisms that appear to respond to existing DP training and competence frameworks and those that persist despite advances in technology and procedures. This has clear implications for simulator-based training, competence assessment, and curriculum development within DP training centres.

Overall, the study shows how longitudinal incident data can be used not only to test risk models, but also to support more grounded, human-centred approaches to education and training aimed at improving safety in digitally intensive maritime operations.

Investigating Human Factor in ECDIS-Related Maritime Accidents: Insights from Investigation Reports and Proposals towards Safety Improvements

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Keywords: safety of navigation; ECDIS; maritime accidents; human reliability analysis; human factor

The Electronic Chart Display and Information System (ECDIS) serves as the primary interface through which Officers of the Watch (OOWs) perceive, interpret, and manage the navigational environment. By structuring information and integrating multiple sensor inputs, the system supports voyage planning and monitoring, as well as hazard assessment throughout all phases of the voyage. Its contribution to safety, therefore, depends on how this mediated representation of the environment is understood, accepted, and used within the operational and organisational context of the navigational bridge (Hasanspahić et al. 2025; Car et al., 2020). This study analyses maritime accidents involving ECDIS (MAIB 2025; DMAIB 2025; MSIU 2025; BSU 2025; BEAmer 2025; NTSB 2025; TAIC 2025), and uses the Human Factors Analysis and Classification System for Maritime Accidents (HFACS-MA) (Adumene et al. 2022; Chen et al. 2013). The results indicate that accidents are rarely associated with technical and/or system failure. Instead, they are predominantly linked to routine violations, inadequate supervision, and organisational climate, pointing to weaknesses within the human operating environment. To complement the findings, Port State Control (PSC) inspection data from the Australian Maritime Safety Authority (AMSA) (AMSA 2025), and Tokyo and Paris Memorandums of Understanding (Tokyo MOU 2025; Paris MOU 2025) were examined, revealing recurring deficiencies related to Electronic Navigational Charts (ENC) management, system configuration, alarm handling, and operator competence. Navigation safety outcomes stem from the interaction among human operators, technological systems, and the operational environment. In complex navigational settings, inappropriate configuration or selective use of system functions can distort the representation of environmental risk, directly impacting OOW's situational awareness. At the voyage level, inconsistencies in training, supervision, and procedural control weaken the role of ECDIS as a reliable, primary navigational means. Further safety improvements will depend on treating ECDIS as a socio-technical control system rather than a standalone technical aid. Priority actions include focusing training on operational use and configuration practices, strengthening simulator-based system assessment, integrating it more explicitly into bridge resource management, and aligning organisational procedures with actual practice. Addressing these areas is essential for translating the technical capabilities of ECDIS into consistent and measurable safety outcomes in maritime navigation.

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Integrating Cognitive Bias into HFACS for Maritime Accident Analysis: Evidence from the Bosphorus Tanker Collision

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Keywords: human factors; HFACS; maritime accident; cognitive bias; navigation safety

This study proposes an integrated methodological framework that combines the Human Factors Analysis and Classification System (HFACS) with structured cognitive bias mapping to enhance causal analysis in maritime accident investigations. The framework extends conventional HFACS application by explicitly incorporating cognitive mechanisms that influence operational decision-making under conditions of uncertainty, stress, and environmental constraints. A retrospective qualitative case study design was applied using a tanker collision in the Bosphorus Strait as an empirical validation case. The analysis used the DoD HFACS 8.0 taxonomy alongside a systematic protocol for identifying cognitive biases. Five maritime subject-matter experts independently coded fifteen operational events, and an inter-rater reliability assessment was conducted to evaluate consistency in classification. The integrated analysis demonstrated that cognitive biases function as mediating mechanisms, linking systemic conditions, and unsafe acts. Unsafe Acts and Preconditions were the most frequently identified HFACS categories, particularly delayed maneuvering, excessive speed, degraded situational awareness, and procedural fixation. Cognitive bias mapping identified overconfidence bias, confirmation bias, the authority gradient, and the normalization of deviance as key contributors to navigational judgment and action selection. The proposed framework improves explanatory depth, causal transparency, and analytical resolution compared to traditional HFACS applications. The model provides a structured and reproducible method for identifying cognitive-system interactions. This approach supports the development of targeted safety interventions, training programs, and safety management strategies for operations in constrained and high-risk maritime environments.

The Role of Navigation Simulators in Developing Seafarers' Safety Competencies and Reducing Human Error in Navigation

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Keywords: navigation simulators; navigation safety; seafarer training; human error

The safety of navigation in modern maritime transport depends on the level of seafarers' competence and their ability to make the right decisions in complex and stressful navigational situations. Navigation simulators are an important tool in the education and training of seafarers. In accordance with international training standards, they enable the acquisition and practice of various skills in safe and controlled environment. The aim of the paper is to investigate the contribution of navigation simulators to the development of safety-related seafarers' competencies and their impact on reducing the risk of human error in navigation. The paper analyses relevant professional and scientific literature, as well as International Maritime Organization standards, with special emphasis on the STCW Convention and IMO Model Courses. A bibliometric analysis using the VOSviewer software was applied to systematically review the literature, identify thematic research groups and the most significant contributions in the field of navigation simulators. The empirical part of the study is conducted through a survey-based research approach involving maritime students and seafarers. The collected data are analysed using statistical methods with the aim of assessing the perception of the effectiveness of simulation systems in education and training. The research results indicate the positive impact of navigation simulators on the development of navigation and safety competencies of seafarers. The findings confirm the importance of navigation simulators as a key element of the modern system of education and training of seafarers in the function of improving navigation safety and reducing the probability of human error in real-world situations.

Maritime Trainees' Responses to Unexpected Navigation and Technical Failures: A Simulator-Based Eye-Tracking Study

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Keywords: human factors; situational awareness; eye-tracking

Human factors are widely cited as the primary cause of maritime accidents. Causes may vary from fatigue, stress, high cognitive load, pressures, workload, decision-making errors to many more influenced factors (Maternová, (2019), (Russo, 2022) leading to reduced situational awareness which is identified as key risk factor contributing navigational errors and incidents (Vojković et al., 2021). Assessing cognitive focus and stress responses during navigation remains a challenging task, as these factors are highly individual and influenced by variables such as experience, training, knowledge, and innate predispositions.

In this paper the cognitive performance and physiological responses of maritime trainees during simulator-based exercises are presented, with a focus on reactions to technical and navigational errors. An automated analysis pipeline was developed to transform raw gaze data into interpretable behavioral scores. In order to better understand the reaction of trainees and improve simulation exercise scenarios on a nautical simulator, and ultimately better prepare future officers for navigation, research was conducted on a nautical simulator that connects nautical knowledge and reaction to unwanted situations during navigation. The aim of the research is to examine how participants perceive, process, and respond to unexpected malfunctions or deviations from GPS errors, AIS errors, and complex maritime navigation environments, using objective measures of visual attention and physiological load.

This study builds on existing research to better understand how maritime experts and trainees perform during emergencies. We expect that experienced mariners will use their vision more efficiently. They should spot problems faster, switch their gaze between important screens (like ECDIS and RADAR) in a more predictable order, and return to normal operations more quickly after an incident. In contrast, novice trainees will likely show signs of higher workload and stress. Their gaze might jump erratically between screens, stay too long on non-critical areas, or become unfocused, and they may take longer to recover their focus after a surprise event. A key goal is to link these visual patterns to the body's stress response. We hypothesize that calm, efficient eye movements will be paired with a stable heart rate, while frantic, scattered looking will occur alongside a racing heart, providing an objective measure of panic.

The research was conducted using a maritime navigation simulator combined with eye-tracking glasses to monitor eye movements (Petrović et al., 2025), (Win et al.,2026) and measurements of heart rate and blood pressure to assess stress and cognitive workload. Eye tracking enabled the analysis of visual attention patterns during night navigation in high density traffic, including fixations and reaction time to potential collision situations, while physiological parameters served as indicators of stress levels and cognitive strain. During the simulation sessions, deliberate technical and navigational errors were introduced to evaluate detection speed, decision making strategies, and subsequent behavioral and physiological changes.

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An Open-Source, Low-Cost Navigation Console for Maritime Education and Research

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Keywords: maritime simulator; command console; open-source; low-cost; training

Maritime navigation simulators have become an essential tool of maritime education and training. They enable the realistic reproduction of a wide range of operational maritime scenarios at significantly lower cost and without the safety risks associated with onboard training. These simulators incorporate multiple vessel types, allowing mariners to train for diverse navigational contexts. They also make it possible to simulate emergency situations such as onboard fires, man-overboard events, or machinery failures. Due to their pedagogical value and the limited number of students who can use them simultaneously, simulator platforms are often heavily utilized. As a result, simulator training hours are typically constrained, and students frequently express the need for additional practice time.

To address this limitation, commercial desktop, cloud, and Virtual Reality based simulators are available (Tusher et al. 2024), along with open-source and free solutions such as Bridge Command[1]. On the hardware side, dedicated commercial control consoles are designed to provide a more immersive maritime experience (Dahlstrom et al. 2009). However their cost, often several hundred euros, generally restricts their use to maritime institutions. Moreover, these proprietary consoles offer limited flexibility for modification or integration with innovative systems. This is particularly relevant in the context of emerging technologies such as Wind-Assisted Ship Propulsion (WASP) systems, which are gaining increasing attention as part of the maritime sector's decarbonization efforts. A project proposes controls but with rare components and poor documentation[2].

Within the SOMOS project[3], we aim to develop innovative educational tools that integrate wind-assisted propulsion concepts into maritime training (Rieffel et al. 2025). This paper presents the first version of a navigation console developed as part of this initiative. The design objectives of this console are: (1) open and free reproducibility; (2) adaptability and scalability; (3) low cost; (4) ease of assembly and implementation; and (5) reliance on widely available, standard components.

To achieve these goals, we propose a fully documented, open-access solution available online. The resources include laser-cutting design files for constructing the console enclosure (see Figure 1), electronic wiring schematics, the required software, and comprehensive documentation to support replication and installation. The system is designed to be compatible with existing simulation software while remaining modular enough to integrate additional functionalities, such as auxiliary sail propulsion control interfaces.

This paper details the technical design specifications process of the console and explains how it is used through SOMOS project. By providing an accessible, low-cost, and adaptable alternative to commercial solutions, this work contributes to expanding simulator-based training opportunities.

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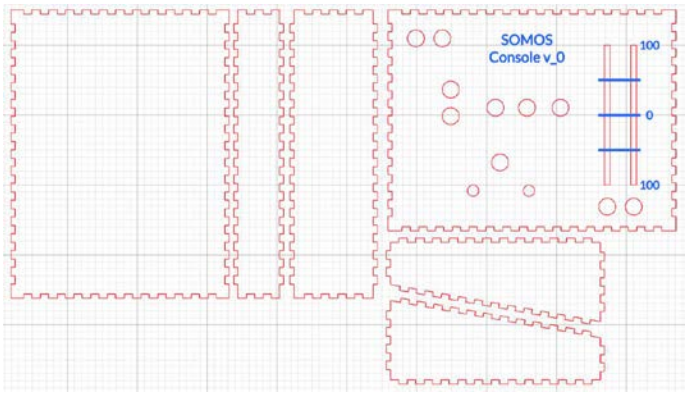


Figure 1. Laser-cutting design files for constructing the console enclosure

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Development of an Innovative Training Module for Automation in the Ship's Bilge Pumping System

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Keywords: innovative training module; automated ship's bilge pumping system; IoT training module

The rapid advancement of automation and digital technologies in the maritime industry has intensified the demand for marine engineers who possess not only strong theoretical knowledge but also practical, hands-on competencies aligned with modern shipboard systems. One critical area of ship operation is the bilge pumping system, which plays a vital role in vessel safety, machinery space integrity, and environmental protection. Despite its importance, limited access to realistic, functional training equipment at many maritime education institutions continues to constrain students' opportunities to develop operational competence in automated bilge management. Traditional computer-based simulators, while useful, often rely on idealized virtual representations that fail to capture the complexities and irregularities of real shipboard operations.

This study addresses this gap through the design, fabrication, and evaluation of an innovative automated bilge pumping system training module for maritime education. The developed module integrates mechanical, electrical, and electronic components to simulate real-world bilge-pumping operations, allowing students to interact directly with actual pumps, sensors, valves, control logic, alarms, and system interlocks. Unlike purely virtual simulators, the physical system exposes learners to realistic operational conditions, such as response delays, sensor variability, fault scenarios, and safety constraints commonly encountered on board ships. The integration of Internet of Things (IoT) technology further enhances the module by enabling real-time data acquisition, remote monitoring, system diagnostics, and performance analysis through digital interfaces, thereby familiarizing cadets with smart ship and automated engine room technologies.

A developmental research design supported by a quantitative approach was employed. The module was designed using circuit and block diagrams and three-dimensional modeling, followed by systematic fabrication and assembly. Evaluation was conducted through operational trials and expert assessment using descriptive statistics. Results indicate excellent performance in terms of reliability, accuracy, adjustability, safety features, and durability. Expert evaluators confirmed that the system effectively simulates shipboard bilge pumping operations and is suitable for instructional use. Moreover, the IoT-enabled configuration provides a resilient solution for maintaining practical instruction during class disruptions such as pandemics and distance learning, allowing remote demonstrations, monitoring, and assessment based on real equipment behavior. The study concludes that the developed training module effectively bridges the gap between theoretical instruction and practical application, enhancing experiential learning and preparing students for increasingly automated shipboard systems. Continued adoption and refinement of similar physical–digital training modules are recommended to support industry-aligned maritime education and competency-based training.

Development and Evaluation of a Digitalized Instruction Software for Collision Regulation Rules 13-18

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Keywords: collision regulation; digitalized instruction; software development; maritime education; simulation-based learning

The majority of maritime incidents result from human mistakes. In numerous instances, the level of watchkeeping was inadequate, or the watchkeeper lacked the necessary skills. Numerous accidents that occurred in recent times resulting in hundreds of deaths have highlighted the human element, the importance of training, the function of the incident commander, making decisions under pressure and the environment in maritime safety (Havold 2010). Anyone responsible for a vessel is obligated to accurately apply the Collision Regulation in every situation to ensure their own safety and the safety of other vessels navigating the seaway.

The Collision Regulation (ColRegs), formally known as International Regulations for Preventing Collisions at Sea 1972, apply to all vessels operating on the high seas and in all connected waters that are navigable by seagoing ships, thereby providing a universal framework for the safe conduct of vessels at sea (IMO 2024). ColRegs are designed to prevent maritime collisions, and these regulations are vital as they are applicable globally (Deckee 2024).

Numerous institutions offer thorough and comprehensive training and educational programs for the proper implementation of Collision Regulation (Demirel & Bayer 2015). However, due to the frequent occurrence of collision incidents caused by human error in navigation, there is a growing need for more accessible and effective training methods for teaching the steering and sailing rules of Collision Regulations. Technological innovation plays a vital role in enhancing maritime students' learning experiences by improving situational awareness, decision-making, and mastery of ColRegs. One approach is the development of computer-based steering and sailing software that allows students to practice anti-collision maneuvers in the classroom without relying on costly full-emission bridge simulators, providing a more convenient and practical method for applying Collision Regulation principles.

This study aimed to develop a digitalized steering and sailing instructional software designed to enhance maritime students' competencies in applying Collision Regulation Rules 13 to 18 within a classroom environment. Guided by the ADDIE Model, the study identifies students' learning difficulties in understanding overtaking, head-on, crossing situations, and responsibilities between vessels, which establish the need for an accessible, simulation-based learning tool that does not rely on full-mission bridge simulators. In the Design and Development Stages, the software prototype was built using Unity, C#, and JSON, integrating realistic navigational scenarios, maneuvering controls, environmental elements, feedback prompts, and interactive features to support experiential and constructivist learning. Implementation with 37 maritime students generated qualitative feedback highlighting key areas for refinement, including speed adjustments, improved realism, enhanced interactivity, personalized feedback, and interface usability. During the Evaluation Stage, 37 students and three experts assessed the software's usability, functionality, reliability, and performance, yielding high to very high acceptability ratings. Findings indicated that the software effectively simulates real-world collision-avoidance situations, improves learner's situational awareness, and strengthens their decision-making skills in applying COLREG rules 13-18. Overall, the digitalized instruction developed in this study demonstrates strong potential as an efficient, practical, and pedagogically sound supplementary tool for maritime education.

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Table 1. Distribution of Respondents

Category	f	%
Entire Group	37	100
A. 1 intact section (Implementation Stage)	37	100
B. 1 intact section (Evaluation Stage)	37	100
C. all ColReg instructors (Acceptability Stage	3	100

Table 2. Acceptability & Satisfaction Scale

Mean Scale	Acceptability Rating	Satisfaction Rating
3.51 – 4.00	Very High – Minimal revisions needed	Excellent – Highly effective software
2.51 – 3.50	High – Good but needs revisions	Sufficient – Meets training expectations
1.51 – 2.50	Low – Requires major modifications	Insufficient – Does not fully meet needs
1.00 – 1.50	Very Low – Software should be revised or discarded	Not Usable – Ineffective training tool

Table 3. Summary of Students' Feedback on Software Prototype during the Implementation Stage

An example of a column heading	f	%
1. Enhancement of Vessel Speed and Maneuvering Controls	9	36
2. Realism and Accuracy of the Simulation Environment	5	20
3. Improved Interactivity and Gamification Features	4	16
4. Need for More Personalized Feedback and Error Correction	3	12
5. Usability and Interface Improvements	4	16

Maritime English as a Safety Infrastructure: Towards Sustainable Communication Standards in Digital Green Oceans

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Keywords: maritime English; sustainability; safety; digitalization; human-error

Green oceans represent not merely an environmental aspiration but a governance architecture spanning the entire lifecycle of maritime systems—from ship design and construction to operation and final decommissioning. The trajectory toward zero emission, zero waste and progressively autonomous maritime environments, evolving from reduced-human operations to unmanned systems, requires enforceable standards, regulatory harmonization and digitally integrated oversight. In such an environment, operational coherence becomes a systems-level requirement rather than an organizational preference. Despite regulatory consolidation and technological sophistication, human error continues to function as a structural determinant of maritime casualties. Accident investigations consistently demonstrate that communication breakdowns operate as latent conditions that enable unsafe acts. Within a multinational and multicultural maritime ecosystem, linguistic asymmetry and communication inefficiency introduce systemic risk factors that compromise procedural integrity. These risks are not confined to bridge-centered navigation but extend across the full operational cycle of commercial shipping, encompassing cargo management, maneuvering coordination, engine-room interaction, maintenance execution, port-state interface and onboard decision chains. Consequently, Maritime English competence cannot be treated as a limited phraseological tool restricted to SMCP; it must be understood as an operational infrastructure underlying all merchant vessel activities. Communication inefficiency constitutes organizational entropy within complex maritime systems. Ambiguity, inconsistency and interpretative variability degrade operational reliability and increase the probability of safety-critical deviation. In digitally governed maritime environments, such inefficiencies contradict the foundational premise of green ocean governance: predictability, traceability and systemic resilience. The aim of this study is to reconceptualize Maritime English as a safety-critical and digitally anchored governance instrument rather than as a conventional language qualification. Employing a qualitative research methodology, the study conducts regulatory analysis, examines safety management doctrines, evaluates the human error framework and performs a structured gap analysis between SMCP-based communication standards and the broader operational requirements of commercial shipping. On this basis, a conceptual model for digitally reinforced and periodically harmonized competence standardization is developed. The ultimate objective of this conceptual investigation is to establish the theoretical groundwork necessary for the future development of an AI-supported VR Digital Maritime English Lecturer Agent capable of adaptive benchmarking and scenario-based reinforcement. As maritime operations transition toward reduced-human and unmanned configurations, digitally integrated communication architectures will constitute a prerequisite for ensuring safety, security, reliability, robustness and sustainability within digital green oceans.

It is concluded that sustainable maritime governance cannot be achieved solely through environmental regulation or technological innovation; it requires the systematic digital standardizations, continuous reinforcement and lifecycle management of operational communication competence across the global maritime community.

Digital Approaches to Seafarer Certificate Renewal: Enhancing Flexibility and Objectivity in Knowledge Assessment

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Keywords: seafarer certification; maritime education and training; digital assessment systems; platform based learning environments; maritime sustainability

The current system for renewing seafarer certificates relies primarily on classroom-based refresher training, requiring a significant time commitment and reducing available rest periods. This approach affects work organization and generates additional costs for both training institutions and maritime companies. As the theoretical requirements associated with certification change only marginally over time, the efficiency of traditional training models has become increasingly questionable. The author argues that contemporary digital technologies offer a viable alternative for supporting the assessment of seafarers' theoretical knowledge and the certificate renewal process through a flexible, platform based digital environment accessible across different devices and operational settings. The proposed approach enables the delivery of learning materials and structured, time restricted knowledge assessments, ensuring a consistent level of difficulty, supporting result comparability, and reducing the risk of unfair practices through dynamic question selection and activity traceability. In addition to conceptual analysis, the article incorporates input collected through a targeted questionnaire distributed among maritime companies, educational institutions, and training centers, providing practical perspectives on the applicability of the proposed solution. The author conclude that the digitalization of certificate renewal processes has the potential to enhance efficiency, flexibility, and sustainability while maintaining compliance with established regulatory principles, as well as improving the objectivity of knowledge assessment and reducing time consumption and environmental impact within the maritime sector.

Improving IMO SMCP and GMDSS Competence AI-Assisted Maritime English Teaching (at the example of BSMA Study)

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Keywords: maritime communication; emergency response; IMO SMCP; GMDSS; safety at sea

Effective communication in Maritime English is a cornerstone of maritime safety, particularly during emergency situations where rapid, clear, and standardized message exchange is essential to protect human life, vessels, and the marine environment (IMO, 2001; STCW, 2011). Within maritime education, Maritime English serves as the linguistic foundation for applying the IMO Standard Marine Communication Phrases (SMCP) and operating within the Global Maritime Distress and Safety System (GMDSS) (IMO, 2001) While GMDSS provides the global technological framework for transmitting distress alerts and coordinating search and rescue operations, SMCP ensures clarity and reduces misunderstandings through internationally standardized phraseology (IMO, 2001; Weintrit & Neumann, 2016).

This study examines the role of AI-assisted tools in enhancing the teaching of maritime emergency communication within the Maritime English classroom. To evaluate the effectiveness of AI-supported instruction, a structured survey was conducted among maritime students to assess their theoretical knowledge, communication confidence, and ability to apply standardized emergency communication procedures in English. The survey measured students' understanding of SMCP and GMDSS message structure, their confidence in emergency communication, and their perceptions of AI-based teaching tools. Scenario-based questions required students to analyze simulated emergency situations and identify the appropriate distress priority (MAYDAY, PAN-PAN, or SECURITE), while also demonstrating correct use of Maritime English by applying IMO SMCP phraseology and proper GMDSS message structure (IMO, 2001; STCW, 2011).

The results suggest that integrating AI into Maritime English education strengthens emergency communication competence, supports instructors through targeted feedback mechanisms, and contributes to the preparation of safer and more digitally competent maritime professionals.

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Bridging the Safety Gap: A Literature-Based Analysis of MET Readiness for the Green Hydrogen and Ammonia Transition

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Keywords: green hydrogen; ammonia safety; competency gap analysis; maritime education and training (MET); decarbonisation

The International Maritime Organization's (IMO) 2023 GHG Strategy has accelerated the maritime industry's transition towards zero-emission fuels, with green hydrogen and ammonia emerging as primary contenders (DNV 2023). While the technological feasibility of these carriers is increasingly well-documented, the "human element", specifically the readiness of Maritime Education and Training (MET), remains critically under-researched. Unlike Liquefied Natural Gas (LNG), which has established training protocols under the IGF Code, hydrogen and ammonia introduce distinct and severe safety hazards. Recent dispersion modelling studies indicate that ammonia releases from damaged storage tanks pose significantly higher lethality risks due to acute toxicity compared to conventional fuels (Masia et al. 2024). Furthermore, the unique cryogenic requirements and hydrogen embrittlement risks require specialised material handling knowledge currently absent from standard curricula (Shi et al. 2023). Venkadasalam (2023) highlights that without a targeted "Ammonia-Ready" training programme, the industry faces a severe skills shortage that could compromise operational safety.

This paper aims to address this disparity by conducting a Systematic Literature Review (SLR) guided by the PRISMA statement. It will employ bibliometric analysis to map the evolution of safety research and marine operations regarding alternative marine fuels over the last decade. By comparing the technical engineering literature against current MET framework, including the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) and the International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels (IGF Code), this paper seeks to identify strategic gaps in workforce preparation.

It is anticipated that the analysis will reveal a significant lag between the rapid advancement of fuel technologies and the adaptation of MET curricula. Preliminary observations suggest that current training, which heavily emphasizes fire prevention (legacy LNG protocols), may be insufficient for handling toxic ingress or cryogenic containment failures associated with NH3 and H2. Ultimately, this paper intends to develop a conceptual "Future-Ready" competency matrix. This will provide a vital roadmap for MET institutions, identifying the specific theoretical knowledge and simulator scenarios required to ensure the safety of the future workforce during the fleet transformation.

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Towards Shipping Decarbonization: Experimental Assessment of Hybrid Battery-Fuel Cell Electric Propulsion System

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Keywords: PEM fuel cell; hybrid propulsion; hydrogen safety; seafaring; shipping; autonomous ships; competency; mass

The global decarbonization initiatives with stringent environmental standards necessitate the maritime industry to adopt zero-emission propulsion technologies. This paper reports on an IAMU funded project that experiment the hydrogen as an alternative fuel for decarbonising the future ships. We present a detailed design, integration, and field evaluation of a Proton Exchange Membrane (PEM) Hydrogen fuel cell based electric propulsion system for a small-scale experimental scaled down boat. The propulsion system comprises of a 5-kW electrical propulsion system powered by a hydrogen PEM fuel cell stack coupled with a 100 Ah, 48 V Lithium iron phosphate (LiFePO4) battery to manage transient power demands and improved propulsion load handling capabilities. The Permanent Magnet Synchronous Motor (PMSM) electric propulsion is rated at a peak power of 5-kW, controlled via a custom developed motor controller with real-time power management algorithms. The power management system offers a state of charge (SOC) based control strategy to optimize energy flow between the fuel cell and the battery. The hybrid propulsion system architecture ensures efficient operation of the propulsion plant and prolonged battery life. To meet the maritime hydrogen handling requirements we devised a safety system for hydrogen storage and delivery with integrated pressure sensors, solenoid valves and fail-safe shutoff mechanisms. Field tests were conducted under controlled inland water conditions, crucial data were collected such as propulsion motor power output, battery SOC, boat speed, hydrogen consumption rate, and temperature profile of the PEM fuel cell system. Results demonstrated a very stable propulsion power delivery with an excellent transient response and an improved in specific energy usage compared to battery only electric propulsion. The hybrid electro-hydrogen PEM fuel cell propulsion system extends the expected operational range with zero direct carbon emissions throughout its operation. Key practical challenges addressed include compressed hydrogen storage limitations, fuel cell thermal management, and system cost/complexity for small-scale applications. This pilot project demonstrates the feasibility of a pathway towards safe and green maritime operations. This project also provides opportunity for developing competency required for seafarers to work on board Hydrogen powered PEM Fuel Cell Ships.

Acknowledgements

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Benchmarking Winter and Polar Shipping Competencies: Finland-the United States-Australia Comparison

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Keywords: competency benchmarking, environmental protection; ice navigation; Polar Code; STCW

Interest in polar shipping is increasing in both Arctic and Antarctic waters, as new routes are expected to be established in the coming years. Polar maritime operations demand specialized competencies that extend beyond conventional shipping skills. The International Maritime Organization (IMO) Polar Code (International Maritime Organization n.d-a.) and STCW requirements provide the basis for these competencies, but implementation practices vary across regions and organizations.

This study presents a cross-regional study of polar shipping competencies at maritime universities in Finland, the United States, and Australia. The study consisted of 1) benchmarking current competency profiles in polar shipping, 2) identifying potential gaps and emerging skill needs, and 3) proposing pathways to strengthen MET competencies through training, assessment, and knowledge exchange. Environmental and nature-related competencies were also studied as an integrated dimension of responsible polar operations.

A mixed-method benchmarking approach was applied in the study regions. The study combined a structured review of regulatory requirements, training standards, and guidance documents related to the Polar Code and STCW polar training, and a comparative competency matrix and gap analysis. Competencies were assessed across technical, human, organizational, digital, and environmental domains and validated through cross-case comparisons. Results show that Finland represents a mature winter navigation and icebreaking assistance system, supported by long-standing operational experience, coordinated traffic management, and ongoing competency development initiatives such as the WINMOS III project (WINMOS III n.d.-a.). Globally, 80% of icebreakers are designed, and 60% are built in Finland. The United States contributes perspectives on regulatory oversight (US Department of Homeland Security 2018), polar navigation courses as "continuing education," and polar education in maritime academies, such as in Maine and Massachusetts. Australia provides expertise from Antarctic logistics operations and established Polar Code training capacity through its maritime education and regulatory framework (AMC Research n.d-a.). Together, the three countries offer complementary insights into the development of polar and cold-region maritime competence.

The results of this study contribute to harmonizing MET development polar capable maritime nations and offer a transferable methodology for future international cooperation in polar shipping education, training, and research.

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A Comparative Performance Analysis of Nuclear Marine Propulsion Plants using Supercritical CO2 and Conventional Steam Cycles

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Keywords: nuclear marine propulsion; supercritical CO_2 cycle; Rankine cycle; energy efficiency; power density

Nuclear marine propulsion systems developed to date have predominantly relied on the superheated steam Rankine cycle (Carlton et al., 2011), which, despite its technological maturity and proven reliability, presents significant limitations in terms of component size, complexity of installation and overall thermal efficiency (He et al., 2022).

The aim of this study is to conduct a comparative thermodynamic and dimensional analysis of marine propulsion plants based on the conventional steam Rankine cycle and an alternative supercritical CO_2 Brayton (sCO_2) cycle, considering its application in future nuclear-powered vessels (Li et al., 2024).

Computational models were developed using DWSIM software package, simulating the sCO_2 recompression cycle and comparing it with a superheated steam Rankine cycle typical in marine propulsion installations. For purpose of comparison, the propulsion plant of the LNG tanker Cadiz Knutsen with 28000 kW of output power was considered.

Preliminary results indicate that the sCO_2 Brayton cycle can achieve an overall thermal efficiency approximately 6,20 % higher than the equivalent steam Rankine cycle. Furthermore, a significant reduction in turbomachinery space occupied was found due to the high density of the supercritical working fluid, offering a clear advantage against conventional steam power plants.

In conclusion, sCO_2 power cycle demonstrates potential application for the upcoming generation of nuclear-powered ships, by providing higher power density. However, significant challenges in designing compact heat exchangers and selecting suitable materials remain and will require further research and technological development.

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Qualitative risk analysis on the use of SMR for maritime nuclear propulsion using HAZID and HAZOP methodologies

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Keywords: maritime simulator; command console; open-source; low-cost; training

The growing demand for safe, sustainable and low-carbon energy solutions has renewed interest in nuclear propulsion systems, particularly those based on Small Modular Reactors (SMRs) (Hannaford, 2022; European Commission, 2023). Owing to their compact size, modularity, scalability and inherent passive safety features, SMRs represent a promising technological option for maritime propulsion and onboard power generation (Zohuri, 2023). However, the deployment of innovative nuclear technologies in complex operational environments requires a rigorous and systematic assessment of safety and operational risks throughout the design, operation and maintenance phases.

This paper presents a qualitative risk analysis applied to a reference SMR intended for maritime nuclear propulsion, using a combined approach based on HAZID (Hazard Identification) and HAZOP (Hazard and Operability Study) methodologies (International Standards Organization, 2017; European Committee for Electrotechnical Standardization, 2019). The main objective is to assess the safety and reliability of SMR-based maritime propulsion systems by identifying potential hazards, failure modes and process deviations, as well as their causes, consequences and existing or recommended safeguards.

After a critical review of literature on nuclear safety, SMR design principles and qualitative risk assessment techniques, a SMR is selected and characterized, with particular emphasis on the identification of critical systems and subsystems and their key operational parameters. The HAZID methodology is then applied to identify hazards, threats and risk scenarios, allowing for an initial classification of risks and the definition of control and mitigation measures. In parallel, a detailed HAZOP analysis is conducted, using conventional guide words such as “more”, “less” and “none” to systematically identify process deviations, their potential causes and existing safety barriers.

The results obtained from both methodologies are compared and analyzed, highlighting their respective strengths, limitations and complementarities. While HAZID proves effective for high-level hazard identification and early design decision-making, HAZOP provides a more detailed and structured analysis of operational deviations and system behavior. The combined application of both methods enhances the robustness of risk assessment and supports the development of safer and more reliable nuclear propulsion systems.

The conclusions underline the relevance of qualitative risk analysis tools in the design and operation of SMR-based maritime nuclear propulsion, contributing to improve maritime safety and supporting the development of environmentally sustainable and human-center maritime technologies.

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Explainable AI for Fuel-Consumption Prediction and Decarbonization KPIs Using Long-Term BOEM Operational Data

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Keywords: ship operational data; artificial intelligence; fuel efficiency; decarbonization

The maritime industry is facing increasing regulatory, environmental, and operational pressure to reduce greenhouse gas emissions, reinforcing the need for human-centered digital solutions that support safer and greener ship operations. Previous studies suggest that ship and voyage dynamic parameters can influence fuel consumption (Tilig et al. 2020); however, their impact has not been sufficiently analyzed using large-scale, long-term operational data under real operating conditions.

This paper presents a preliminary study that analyzes a set of routinely recorded ship operational and environmental variables to identify KPIs that can support the reduction of CO_2 emissions. Building on this dataset, we train and validate a high-performing predictive model for fuel consumption and associated emissions and evaluate it using standard evaluation metrics. We then apply explainability methods (Hoang et al. 2025) to quantify the relative influence of each variable under real operating conditions. The most relevant drivers are subsequently translated into interpretable, operationally meaningful KPIs that can be used by shipowners, operators, and maritime professionals to guide greener decision-making.

The study is based on operational data continuously collected since 2013 through the BOEM digital system, which is deployed onboard merchant vessels worldwide and records high-frequency sensor measurements. After data preparation and temporal alignment, the trained model captures the relationship between ship state (e.g., speed, draft, displacement, and cargo), metocean conditions (e.g., wind speed and relative direction), dynamic behavior indicators, and the measured fuel consumption during sea passage, maneuvering, and port/anchorage phases. Along with the prediction of fuel use, CO_2 emissions are estimated using standard fuel-specific emission factors, enabling scenario-based “what-if” analyses (e.g., speed changes, weather exposure, operational phase management) and the derivation of interpretable KPIs that support greener operational decision-making.

By transforming complex operational data into interpretable indicators, the proposed methodology supports informed decision-making, contributes to the education and empowerment of maritime professionals, and promotes safer, more energy-efficient, and environmentally sustainable ship operations within the context of human-centered digital oceans.

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The Role of Consolidator and Specifics of Consolidating LCL Containerised Cargo

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Keywords: LCL - less then container load; container cargo flows; consolidator

This paper analyses the specific features of forming and consolidating Less then Container Load (LCL) cargo flows as a logistics solution that bundles smaller consignments from different shippers into a single consolidation container. Such an approach contributes the cost optimization and increased efficiency in international trade in goods.

In the context of the growing importance of LCL transport within global supply chains, the study focuses on analyzing the consolidation process and the role of the consolidator in the logistics and distribution of groupage containers. Alongside the theoretical framework, the issue is examined through a practical case study of consolidator's operations.

The aim of the paper is to analyze the consolidator's role as a Third-Party-Logistics (3PL) operator in rationalizing and optimizing LCL flows. The scholarly contribution of this research lies in evaluating the consolidator's role in optimizing containerized cargo flows and in identifying the key elements and drivers of effective LCL shipment management. The findings may serve as a basis for further research and for improving logistics processes in international containerized trade.

Fisheries Control System Regulation and Technologies

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Keywords: vessel monitoring system; fishing effort; marine protected areas; global navigation satellite systems; wireless sensor networks; satellite communications

Fisheries Control and management of resources based on scientific data for a sustainable development of human activities in marine environments is one of the most ambitious and urgent challenge in modern societies. Management fishing resources plays an important role in blue economy with social and environmental impacts. Improving and developing the future of fisheries human centered digital ocean will improve in future a more sustainable and resourceful ocean and will contribute for knowledge of marine life at sea.

New EU regulation 2025/2196 of 17 October 2025 establishes rules regarding access to water and resources, control of fisheries, surveillance, inspection and enforcement, deduction of quotas and fishing efforts, data and information. Such transition will entry into force and application from 10 July 2027 onwards to all member states, with implications in technological solutions to implement on each fishing Vessels Monitoring System (VMS) with different requirements according with different LOA (Length Overall), changing responsibilities of the Master of a Union fishing vessel, impacts in coastal Member state Control Centre. If on one side there will be also changes in fishing logbooks, prior notifications, transshipment declaration and landing declaration, from surveillance, inspection and enforcement perspective there will be requirements for electronic databases in each Member State. There will be also a database validation system process, and each Member State will exchange fishing activity data with the Commission and European Fisheries Control Agency (EFCA) in a standardized way.

Management and protection of marine fishing species, to increase blue economy, rely on fishing effort temporal and spatial indicators, marine protected areas, marine spatial planning, impact on seabed, bias in stock assessment models amongst others have a response in new EU regulations and result in a future human centered digital ocean. Such information will also help shipowners' decision-making process safer and more profitable for crews and avoiding legal infringements.

Global maritime professionals in a digital era strives for technological solutions at sea. New developing technologies can help Masters, Sailors, Ocean Explorers, Member States, Shipowners, Commission to face new challenges of the blue economy. The evolution of new arising technologies opens opportunities, considering actual requirements from different perspectives, costs, feasibility and reliability.

This paper will evaluate existing technology and solutions based on wireless communication, new satellite communications, sensor networks, image processing, artificial intelligence algorithms, global positioning solutions, FAO fishing marine areas identification, critical infrastructures, redundant secure data bases and management control center, secure reliable exchange of data to other member states, to Commission and EFCA.

This paper summarizes the most relevant documentation requirements for future fisheries human centered digital ocean and envisages new future technological solutions, aggregating related entities with different responsibilities within a common interest in growing a sustainable blue economy in a cleaner safer resourceful ocean.

All data gathered by the system provides information to help decision making process to several entities, the new union Fisherman, the Master, the Crew, Shipowner, Member State, Commission, EFCA, and related entities responsible for the new clean resourceful Ocean also digitally.

How to Increase the Uptake of Digital Solutions in Container Liner Shipping: A Study Based on the Global Introduction of a Digital Berth Alignment Tool

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Keywords: digitalization; container shipping; digital adoption; change management; berth alignment

Digitizing an industry is a mammoth task. Especially, when concerned industry is underlying a traditional mindset and its task are manual and scattered on a global and local scale. However, it is known to eat the elephant best one bite at a time. Therefore, this paper will address the uptake of a digital solution for a sub-task in global shipping: Berth Alignment.

Only developing a digital solution to replace a manual process is one step of the transition. The second step is implementation on a large scale. It will be shown that the uptake, also known as digital adoption, of a digital solution by the stakeholders can be influenced and increased when drawing attention to technology, organization, and the surrounding environment.

This paper will first describe the current state of the art, including the status of the digitalization in the container shipping industry. Next, berth alignment is explained, and its importance described, which grew over the last years under the pressure of the Covid-19 crisis and lack of resources in the maritime world. This is followed by an introduction to the concept of digital adoption.

The methodology of this paper is a mixed method approach combining qualitative and quantitative measures to review a whole range of feedback. The quantitative analysis includes several interviews with early adopters of the software as well as interviews with industry experts and leaders. The qualitative analysis includes the investigation of the “user metrics” from the software providers Analytics Report and the “Waiting Time Outside” (WTO) from the shipping line internal database. Both factors shall demonstrate the uptake of the software over time.

Conclusively, with the findings from the mixed method approach this study works out some favorable conditions to increase the digital adoption of a new software and thus develops recommendations for an even more successful and sustainable implementation of the new digital berth alignment software and process.

Smart Ports in the Digital Era: The Role of Information Technologies in Enhancing Efficiency and Competitiveness

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Keywords: smart ports; digital transformation; economic sustainability; business information systems; port terminals

The increasing complexity of logistics chains and the continuous growth of global trade underscore the need for the development of smart ports as a key mechanism for achieving economic sustainability, competitiveness, and operational efficiency in the maritime sector. Smart ports rely on the application of advanced digital technologies and the integration of business information systems to enhance security, transparency, efficiency, and the environmental performance of port processes.

This paper examines the role and significance of business information systems in the digital transformation of ports, with particular emphasis on the integration of ERP, TOS, and PCS systems into port terminal operations. The analysis addresses the effects of their implementation on resource optimisation, operational cost reduction, terminal productivity, and service quality, as well as the challenges associated with their adoption and integration.

The analysis of collected data indicates that Rotterdam, Singapore, and Hamburg, as observed ports, have entered the process of digital transformation with differing levels of digital maturity, priorities, and implementation strategies. Rotterdam and Singapore have achieved higher levels of digital integration and automation, with Rotterdam leading in the application of advanced technologies such as digital twins and artificial intelligence-based systems, while Singapore applies a centralised and institutionally supported approach to digitalisation. In contrast, Hamburg remains at an earlier stage of digital maturity, primarily focusing its digital initiatives on sustainability, energy efficiency, and the integration of port operations with the urban environment. Despite these differences, the findings confirm that real-time data integration, system interoperability, and the automation of core processes have a significant positive impact on operational efficiency and port competitiveness, while simultaneously supporting alignment with sustainability objectives.

Based on the conducted research, recommendations are provided for the implementation of digital solutions in port systems, with particular emphasis on their adaptability to ports at different stages of digital maturity. The paper contributes to a deeper understanding of the role of information technologies in contemporary port and logistics systems and highlights the importance of strategically guided and systematic digitalisation as a prerequisite for the long-term competitiveness of ports in the context of technological and environmental challenges.

AI-Driven Chatbot Assistance for Enhancing Port Operation and Communication Efficiency

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Keywords: large language models; maritime digitalization; port communication systems; port operations

In current port operations, inadequate documentation and a lack of cooperation may adversely affect the vessel's delivery timelines. Clear comments and optimal use of operational information facilitate interaction, thereby reducing documentation overhead, enabling real-time decision-making over port operations. This research aims to introduce an AI-Chatbot assistant for ports. The system employs Retrieval Assisted Generation (RAG) architecture that integrates port-specific standard operating procedures, customs rules and guidelines, Vessel Traffic Service (VTS) rules, and the clearing process to make the search easy. The assistant provides intelligent, context-aware responses to questions from port staff, ship crew, and agents via a unified interaction pipeline integrating a chatbot. The proposed concept is well-suited for port environments as it can understand communication in any language, perform document translation, provide security support, and help in operation. Out Study showed faster reaction times, easier work, and more efficient access to vital data during operation. The proposed methodology shows how Large Language Model (LLM) based systems can turn the classical port communication into a fully automated, intelligent, and user-friendly support for smart ports.

Data Governance and Data Quality Metrics in the Maritime-Port Sector: A Systematic Literature Review

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Keywords: data governance; data quality metrics; smart ports; data consistency; operational value

The maritime–port sector is undergoing an accelerated transformation driven by digitalisation, automation, and the adoption of technologies such as IoT, Big Data, and Artificial Intelligence. In this new context, ports are evolving into complex digital ecosystems, where operational efficiency, transparency, and sustainability increasingly depend on the ability to collect, integrate, and use data from multiple sources and stakeholders (Tijan et al., 2021; González-Cancelas et al., 2024). However, despite growing investment in digital solutions, the sector's maturity remains uneven and is marked by inter-organisational coordination difficulties, security challenges, and the lack of consolidated digital governance practices, which limits the creation of value from data (González-Cancelas et al., 2024). The literature reinforces that port governance must keep pace with this transition, recognising the role of port authorities as strategic actors in the implementation of collaborative platforms, such as Port Community Systems (PCS), which can promote the secure and efficient exchange of information and support the sustainability of operations (Tijan et al., 2021).

Despite the increasing relevance of the topic, a critical gap remains: technological adoption tends to progress faster than data governance and quality assurance mechanisms, undermining the consistency and reliability of the information used in operational decision-making. In particular, evidence shows that in the adoption of IoT in smart ports, data governance has not yet kept up with sector requirements, with notable weaknesses in data lifecycle management and data quality management (Gao et al., 2024). In parallel, recent approaches highlight that research on smart ports and automation remains frequently fragmented and lacks stronger integration across technological, institutional, and data sovereignty dimensions, which constrains the scalability and interoperability of digital solutions (Zou et al., 2025). Therefore, it becomes pertinent to map and analyse good practices in data governance and data quality metrics applied to the maritime–port sector, with a focus on consistency, reliability, and operational value.

This study proposes a systematic literature review following the PRISMA protocol, with a temporal scope defined between 2015 and 2025, as this interval is sufficiently broad to capture the recent and consolidated evolution of the topic without diluting the focus with outdated approaches. Seventeen articles were reviewed, including conceptual/framework studies, real-world case studies, and surveys, with the aim of identifying data governance practices, models, and mechanisms applicable to the port context, as well as data quality dimensions and metrics oriented towards operational outcomes. To support this analysis, consolidated data quality dimensions such as consistency, accessibility, accuracy, completeness, and timeliness will be considered, with consistency identified as a particularly influential dimension in organisational outcomes (Gao et al., 2024; Zaveri et al., 2016; Syed et al., 2023). It is expected that this work will help reduce the gap between digital transformation and governance maturity by providing a structured mapping of good practices and metrics applicable to the sector, with potential impacts on port efficiency, coordination, and sustainability, while also reinforcing the role of port authorities as orchestrators of digital ecosystems and neutral data stewards.

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Securing the Seas: Privacy-Enhancing Technologies and Human-Machine Interaction in Maritime Cloud Environments

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Keywords: cybersecurity; maritime digitalization; cloud computing; privacy-enhancing technologies

The progressive digitalization of maritime operations has intensified reliance on cloud-based infrastructures to support data-driven decision-making, operational coordination and regulatory compliance across vessels, ports and logistics networks (Surucu-Balci et al. 2024). While cloud services enhance scalability and operational efficiency, they simultaneously introduce complex cybersecurity, data protection and jurisdictional challenges in a sector characterized by transnational operations and fragmented regulatory oversight (Reimsbach-Kounatze et al. 2023).

Maritime stakeholders operate within a layered governance environment in which horizontally applicable data protection regimes, most notably the General Data Protection Regulation (GDPR), intersect with sector-specific frameworks developed under the International Maritime Organization (IMO), including non-binding guidelines on maritime cyber risk management (International Maritime Organization 2022). This regulatory interaction creates legal uncertainty concerning responsibility, cross-border data transfers and compliance obligations when operational or personal data are processed through globally distributed cloud services (Soyer and Tettenborn 2021).

In this context, the paper assesses the role of Privacy-Enhancing Technologies (PETs) as practical mechanisms for enabling secure data sharing, while mitigating privacy and confidentiality risks (Leloudas 2021). Focusing on encrypted data processing, pseudonymization and decentralized data analysis models (Li et al. 2020), the study evaluates how existing PET approaches may address maritime-specific governance gaps. Rather than proposing novel technical architectures, the paper analyzes current applications and conceptual implementations to identify key adoption enablers (including interoperability and regulatory clarity), as well as barriers such as computational constraints, organizational resistance and fragmented oversight (Ngan Van et al. 2022).

The analysis is supported by exploratory findings from a pilot survey of maritime professionals, including operational personnel and instructors. The survey provides empirical insight into perceptions of data sharing, awareness of data protection challenges and attitudes toward PET deployment in operational contexts. Together, the legal, technical and empirical perspectives contribute to an assessment of the conditions under which PETs can realistically enhance cybersecurity and data governance in maritime cloud ecosystems.

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An Overview on Cybersecurity in the Maritime-Port Sector

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Keywords: cybersecurity; cyber risk; vulnerable systems; digital piracy; digital security

Cybersecurity, defined as a set of processes, best practices, and technological solutions that help protect critical systems, data, and networks against digital attacks, has been a central topic in the international maritime community recently. Since 2017, a year particularly plagued by digital attacks on the maritime-port sector, e.g., the NotPetya malware attack at Maersk irreversibly encrypting bootloader registers of main computers, the International Maritime Organization (IMO) has paid special attention to the issue of cybersecurity, particularly in regulatory terms. In fact, in 2016, the IMO's Maritime Safety Committee (MSC) approved document MSC.1/Circ.1526 that, namely, identifies vulnerable systems and defines the functional elements that support effective cyber risk management, leading to the MSC-FAL.1-Circ.3 document the following year. This circular, in turn, has undergone regular updates, demonstrating the organization's commitment to updating systems in terms of digital security and raising awareness among all personnel involved in the sector, being directly integrated in IMO's Model Courses 3.24 of 2018 on Security Awareness Training for Port Facility Security Personnel with Designated Security Duties, and 3.26 of 2023 on Security Training for Seafarers with Designated Security Duties. In line, Resolution MSC.428(98) was created in 2017, placing cybersecurity in the International Management Code for the Safe Operation of Ships and for Pollution, while providing additional safe practices in the operation of ships and a safe working environment. Also recently, in 2021, the International Association of Ports and Harbors' proposed MSC104/7/1 guidance circular was approved. The fundamental documentation, listed below, will be surveyed in this paper, with emphasis on the corresponding key aspects:

- MSC.1/Circ.1526 – 2016 - Interim Guidelines on Maritime Cyber Risk Management
- MSC-FAL.1-Circ.3 2025 - Guidelines on Maritime Cyber Risk Management
- MSC.428(98) – 2017 - Maritime Cyber Risk Management in Safety Management Systems
- MSC 104/7/1 – 2021 - Measures to Enhance Maritime Security - IAPH Cybersecurity Guidelines for Ports and Port Facilities

he International Association of Classification Societies (IACS), as IMO's main technical advisor, assists international regulatory bodies and standardization organizations in developing, implementing, and interpreting statutory regulations and industry standards. IACS Document No. 166 of 2020 is a comprehensive and detailed technical document with several points of relevance: guidelines and reference standards, terms and definitions, functional and technical requirements, verification tests, with a conclusion of utmost importance: prevention is more important than cure, while continuous awareness with efficient and stayed training make shipping safer.

In short, over the last decade, the IMO has encouraged awareness of its own documentation on matters related to cybersecurity applied to the maritime-port sector, focusing on identifying the most vulnerable systems in the sector and the functional elements that support the management and mitigation of the risk of attack and compromise. It is essential to clearly understand the importance of IMO and IACS international regulations in advancing security of digital systems, standing as flagships for economy and global supply chain, in particular.

This paper summarizes the most relevant documentation applied to cybersecurity on the maritime-port sector, focusing on digital piracy planning and attack execution, cybersecurity attack vectors for ships, e.g., entry points, an identification of critical risks, and offers crisis response and prevention proposals for safer maritime transport, with a list of best practices for protecting identity and enhancing digital security in shipping, which include important digital security tools, a set of good prophylactic protection practices and advices.

Human Reliability Assessment in Digitized Maritime Operations Using Data-Driven Bayesian Networks

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Keywords: human-centered digital oceans; maritime safety; Bayesian network; bridge team training; human–automation interaction

Maritime transport is undergoing rapid digitalization transformation, yet accident investigations repeatedly show that safety outcomes still hinge on human-centered performance under real operational constraints. A persistent gap is that evidence on human and digital-interaction contributors is often discussed qualitatively in reports, but is rarely translated into an interpretable, probabilistic model that can quantify how combinations of human, system, and context conditions shift accident outcome severity, information that is essential for designing training that is both safety-critical and operationally credible. This study develops a human-centred "Digital Oceans" accident-prevention model by coding accident investigation reports from 2000 to 2020 into a structured dataset spanning (i) human cognition and decision processes, (ii) human–system interaction attributes, (iii) bridge team factors, and (iv) operational and environmental context. Accident outcome severity is represented as four states: near miss, minor accident, serious accident, and very serious accident. A Tree-Augmented Naïve Bayes Bayesian Network (TAN-BN) is learned from data, with parameters estimated using Expectation–Maximization (EM). Model performance is evaluated using stratified 10-fold cross-validation with one-vs-rest ROC/AUC computed for each severity state. The trained TAN-BN demonstrates strong discriminative capability across severity states, with AUCs of 0.967 (near miss), 0.907 (minor accident), 0.835 (serious accident), and 0.935 (very serious accident), supporting its use as a decision-support and training-design tool rather than a purely descriptive framework.

Model prediction analysis reveals "Very Serious" and "Serious" accidents as dominant outcomes with "Challenging" operational context, "Poor" communication quality, and "High" time pressure as the highest contributing factors. In diagnostic analysis, conditioning on all the accident scenarios shifts posterior mass toward degraded human and team states, most notably Situational Awareness, Decision Making Quality, Bridge Team Performance, and Human System Interaction, with an induced percent change in probability ranging up to 44%. Alongside these, elevated operational stressors such as Operational Context, Environmental Complexity, and Sensor Display Integration had contribution scores ranging up to 89%. Multi-evidence stress stacking scenario analysis produces a sharp escalation: combining poor communication + poor weather/visibility + high time pressure + challenging context yields a 73% posterior probability for Very serious outcomes; a "digital interaction breakdown" bundle (mode confusion, mis-calibrated trust, fragmented displays, ineffective alarms) yields 71% Very serious. Conversely, a "resilient operations" bundle (Operational Context = Normal; HSI = Effective; SA = Adequate; DM = Appropriate) drives catastrophic outcomes to 0% Very serious and concentrates probability in Minor (45%) and Near miss (38%). Likewise, the True Risk Influence (TRI) analysis identifies the Decision-Making Quality, Situational Awareness, and Operational Context as the most critical and highly influential levers for consequence severity. These findings align directly with the conference theme by translating accident-report evidence into training-relevant, human-centered leverage points. The model supports competency-based curriculum design for safe and green maritime professionals by prioritizing modules that reduce digital-era failure modes (alarm and mode management, trust calibration, information overload handling) while reinforcing core bridge skills (communication discipline, role clarity, decision-making under time pressure) under adverse environmental and traffic conditions.

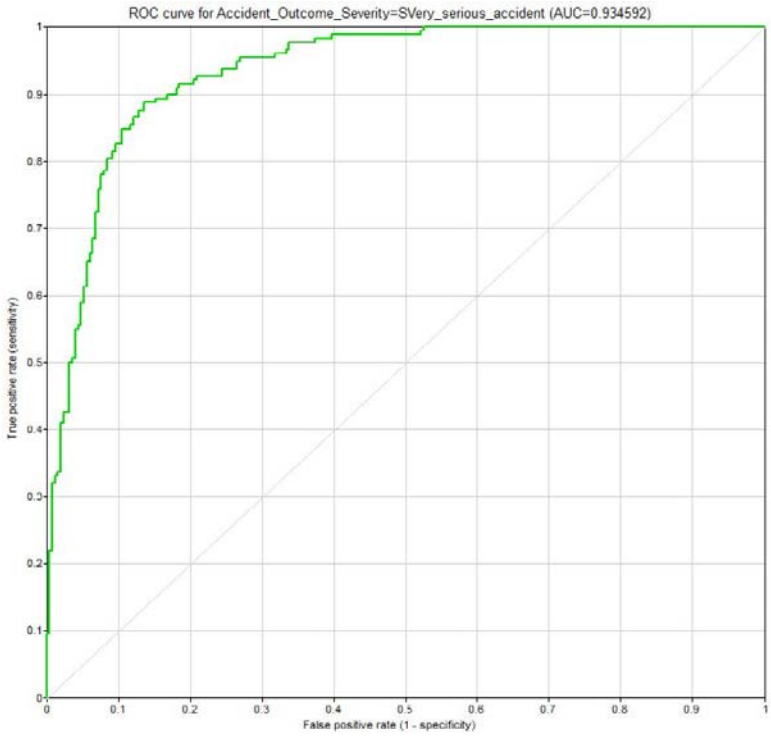


Figure 1. Validation Metrics for the state Very Serious Accidents.

Table 1. Tabulated results for the top five factors of each consequence severity scenario in diagnostic analysis.

Evidence (Accident_Outcome_Severity)	Rank Factor (state shown)	Prior (%)	Posterior (%)	Δ (pp)
Very serious accident = 100%	1 Decision_Making_Quality (Appropriate)	37	7	-30
	2 Situational_Awareness (Lost)	39	66	+27
	3 Decision_Making_Quality (Incorrect)	24	47	+23
	4 Situational_Awareness (Adequate)	27	7	-22
	5 Operational_Context (Challenging)	68	89	+21
Serious accident = 100%	1 Decision_Making_Quality (Appropriate)	37	51	+14
	2 Decision_Making_Quality (Incorrect)	24	12	-12
	3 Situational_Awareness (Lost)	39	28	-11
	4 Training_for_Digital_Systems (Adequate)	79	86	+7
	5 Weather_Visibility (Good)	57	64	+7
Near miss = 100%	1 Operational_Context (Normal)	32	76	+44
	2 Decision_Making_Quality (Appropriate)	37	79	+42
	3 Communication_Quality (Clear)	37	76	+39
	4 Situational_Awareness (Lost)	39	2	-37
	5 Information Overload (Low)	31	63	+32
Minor accident = 100%	1 Situational_Awareness (Adequate)	27	52	+25
	2 Situational_Awareness (Lost)	39	14	-25
	3 Decision_Making_Quality (Appropriate)	37	58	+21
	4 Operational_Context (Normal)	32	52	+20
	5 Sensor_Display_Integration (Integrated)	51	68	+17

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Eye-Tracking in Maritime Operations: A Review of Existing Research

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Keywords: eye-tracking; maritime simulator; maritime training and education; human factors; maritime operations

The application of eye-tracking technologies in the maritime context is increasingly being considered as a tool for better understanding the behaviour and workload of seafarers during complex operational tasks. In the existing literature, eye-tracking is applied in research on navigation, bridge work, engine room work and in seafarer training systems, but the approaches and research objectives of such studies vary considerably. This paper reviews scientific papers indexed in the Scopus database that deal with the application of eye-tracking technologies in maritime operations and education. The search and selection of relevant papers were done in accordance with the PRISMA guidelines. The titles and abstracts of the identified papers were screened to identify whether the research is relevant to maritime operations and training. After that, an extensive review of the selected papers was conducted. The included studies were qualitatively analysed and classified according to the field of application, experimental environment (simulator or real ship) and eye-tracking metrics used. The aim of this paper is to provide an overview of how eye-tracking technologies are applied in the maritime context, including the bridge and engine room work, and to identify directions for future research. In that way, this paper gives directions for usage of eye-tracking as a tool for improving safety at sea and better understanding of human factor role in critical and routine operations aboard ships.

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Ship Safety Domains: Concept Development Review

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Keywords: ship safety domain; maritime safety; navigational risk assessment; collision avoidance; literature review

The Ship Safety Domain (SSD) is one of the most important concepts in research on safety of navigation, navigational risk assessment, and the design of decision-support and collision avoidance systems for both conventional and autonomous ships. An SSD is defined as the area surrounding a vessel that should remain clear of other objects to ensure safe navigation, considering ship characteristics, environmental conditions, and operational constraints. Despite its extensive use in research and applications, there is no universally accepted definition or standardized modeling approach for SSDs. This paper provides a concise review of the current state of research on SSDs. It first examines commonly used definitions and the conceptual foundations of SSDs, highlighting differences in interpretation and scope across the literature, with the emphasis on large commercial ships with more than 3000 gross tons (GT). A general categorization of SSDs is then presented, including static and dynamic domains, deterministic and probabilistic models, as well as geometric, behavioral, and data-driven approaches. The study is based on 20 scientific articles and key studies focusing on modeling assumptions, input parameters, and validation methods. Factors influencing domain size and shape, such as vessel dimensions, maneuverability, speed, traffic density, human factors, and environmental conditions, are discussed. The paper synthesizes the reviewed work to identify prevailing methodologies, limitations, and open challenges, particularly regarding model standardization. The findings provide a structured overview of SSD research and outline directions for future development in maritime safety studies.

Evaluating the Implementation of S-100 Products in National Maritime Systems

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Keywords: S-100 framework; S-57 to S-101 transition; comparative chart evaluation; human-centered navigation; national hydrographic implementation

The transition from S-57 based Electronic Navigational Charts to the International Hydrographic Organization's S-100 framework constitutes a systemic transformation of national maritime information infrastructures. While the technical specifications of S-101 and S-102 are formally established, their operational integration and human-factor implications require structured empirical assessment. The objective of this study is to evaluate the operational and cognitive implications of transitioning from S-57 to S-100 products through controlled comparative testing in real-world pilotage scenarios.

This paper presents a comparative evaluation of legacy S-57 chart environments and prototype S-101 datasets within a national maritime system undergoing digital transition. The research design is based on scenario-driven navigation exercises in confined waters, where S-57 data displayed on shipborne ECDIS are systematically compared with S-100 products integrated into Portable Pilot Units (PPUs). The parallel configuration enables controlled analysis of bathymetric visualization models, data-layer architecture, real-time information integration, and decision-support dynamics.

A qualitative systems-based methodology is applied, combining regulatory framework analysis, operational workflow mapping, and structured expert feedback from licensed maritime pilots operating in high-density traffic areas. The analytical focus encompasses situational awareness, cognitive workload distribution, information prioritization mechanisms, and pilot–bridge coordination processes.

Preliminary results indicate that enhanced bathymetric resolution and multi-layered data integration significantly alter spatial perception and tactical planning structures. However, increased informational granularity introduces elevated cognitive demands, underscoring the necessity for harmonized display configurations and standardized operational protocols.

The findings demonstrate that national S-100 implementation should be conceptualized as a socio-technical transition requiring operational validation and human-factor calibration alongside technical standardization.

Comparative Analysis of Motor Current and Stray Flux Signature Methods for Induction Motor Faults Detection in Maritime Systems

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Keywords: induction motor; stray flux signature analysis; motor current signature analysis; combined faults

Fault detection of induction motors on ships at early stages is very important to ensure the reliability, high performance, and safety of ship operations and navigation. Among different non-invasive fault detection techniques, Motor Current Signature Analysis (MCSA) is a well-established method. In this paper another non-invasive method, Stray Flux Signature Analysis (SFSA) is considered due to its effectiveness and applicability. A comparative analysis of two fault detection techniques is presented based on experimental analysis carried out on an induction motor operating under healthy and faulty conditions in steady state. The experiments are conducted on a squirrel cage induction motor with three different types of faults: broken rotor bar (BRB), bearing fault (BF) and combination of BRB and BF. In this proposed work, SFSA is used by placing a search coil on the motor frame to detect stray flux signals. The MCSA will also be implemented with the use of a current probe to detect the current signals. The signals obtained from both methods will be processed and analyzed, using Fast Fourier Transform (FFT), to extract characteristic harmonics which are attributed to different types of faults. The outcome of this research is expected to provide a better understanding of the application and limitations of SFSA and MCSA in the diagnosis of combined fault.

Intelligent Incipient Fault Detection in Two-Stroke Marine Diesel Engines using Residual Indicators

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Keywords: incipient fault detection; two-stroke marine engines; residual analysis; engine room simulators; condition-monitoring

The digital transformation of maritime systems has increased the availability of operational data, creating new opportunities for human-centred decision support in ship operation and maritime education (Liang et al., 2024). In this context, early fault detection in marine propulsion systems is essential to improve safety, reliability, energy efficiency, and environmental performance. However, detecting incipient faults in large two-stroke marine diesel engines remains challenging due to markedly time-varying operating regimes and measurement streams affected by noise, outliers, and operational/environmental disturbances, which can lead to misidentification.

This paper presents a residual analysis-based methodology for incipient fault detection in a two-stroke main engine (MAN B&W 6S60MC-C). For this investigation, operational time-series data were specifically generated using a Wärtsilä ERS TechSim engine room simulator. This high-fidelity environment enabled the systematic introduction of realistic fault scenarios and the analysis of complex machine behaviour without risk to personnel or physical assets (Wiig et al., 2023). Within this framework, reference neural network models were developed using data subsets obtained during healthy, fault-free operating windows to predict nominal system responses.

Residuals are computed as the discrepancy between measured and predicted values, then normalised per execution using median-based scaling to reduce sensitivity to skewness, outliers, and sporadic measurement errors. These normalised residual features are subsequently aggregated into detection indices and complemented with temporal persistence logic to distinguish sustained degradation from short-lived transients, thereby improving stability and interpretability for operational use.

The methodology is assessed under representative degradation scenarios, including gradual performance deterioration (ramp-type faults) and operating variability designed to emulate sea-state-induced disturbances. Results indicate earlier and more stable fault indication compared to direct thresholding of raw measurements, while maintaining low false-alarm rates—aligning with condition-monitoring and predictive-maintenance principles (Jardine et al., 2006; Zhang et al., 2019). From a human-centred perspective, the proposed workflow enhances situational awareness for marine engineers, supports proactive maintenance planning, and reduces the likelihood of inefficient engine operation. The study highlights the value of combining simulator-driven datasets with intelligent approaches to accelerate transferable onboard condition-monitoring workflows and strengthen digital competencies among future maritime professionals.

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System-Theoretic Safety Assessment of Oil Discharge Monitoring Equipment (ODME) on Oil Tankers

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Keywords: STAMP; ODME; MARPOL Annex I; maritime system safety; tanker ship operations

The Oil Discharge Monitoring Equipment (ODME) on oil tankers is a legally mandated environmental protection system, designed to prevent non-compliant oily water discharge in accordance with the IMO MARPOL Annex I. Despite increased automation and improved equipment design, ODME failures remain a recurring cause of pollution violations. These failures commonly arise from complex interactions among human operators, sensors, control software, hydraulic components, and operational conditions. This study applies a System-Theoretic Accident Model and Process (STAMP) approach to identifying systemic hazards, unsafe control actions, and control–feedback deficiencies of ODME operations.

Using STAMP, a hierarchical safety control structure is first developed to model ODME's interactions across human, hardware, software, and environmental layers. Hazard analysis is then conducted to identify critical vulnerabilities, including incorrect valve actuation, flawed process models within the control unit, inadequate operator understanding of calibration sequences, improper sampling-line configuration, and sensor misinterpretation caused by environmental disturbances. Unsafe control actions are finally classified into four categories, including missing, incorrect, mistimed, or improperly terminated actions, which enables to reveal multiple accident pathways leading to unauthorized or unsafe discharge events.

The findings make new contributions that ODME reliability depends not only on component-level performance, but also on the adequacy of feedback loops, operator mental models, and the enforcement of safety constraints. The STAMP-based analysis provides a holistic system-level understanding of how human, technical, and environmental factors interact to shape ODME safety. This paper therefore offers actionable insights for improving crew training, enhancing system design and alarm logic, and strengthening operational procedures to support environmentally compliant tanker operations.

A Study on Non-Contact Surface Tension Measurement Using Vibration Analysis of Acoustically Levitated Droplets

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Keywords: surface tension; surface tension oscillation; acoustic levitation; sweep

Surface tension is an essential physical property in a wide range of industrial research fields, including ship engineering, particularly in phenomena such as fuel spray formation and lubrication. When practical liquids are considered, conventional contact-based measurement methods, such as the Wilhelmy plate method and the ring method, are highly susceptible to the effects of wettability and solid surface contamination, which often result in limited measurement accuracy and reproducibility.

In this study, a non-contact surface tension measurement method using acoustic levitation was investigated, in which a liquid droplet is levitated in air and evaluated without physical contact.

A liquid sample was introduced into an acoustic levitation device using a micropipette and stably levitated as a droplet. Acoustic waves were irradiated onto the levitated droplet from an external loudspeaker, and droplet oscillations were excited by sweeping the frequency around the resonance region. The oscillatory behavior of the droplet was observed using a high-speed camera, and the resonance frequency was identified. The surface tension was then calculated based on Rayleigh's theory of droplet oscillation (Rayleigh, 1879), using the resonance frequency, droplet radius, and liquid density.

As an initial target liquid, hexadecane, a hydrocarbon with relatively low volatility and widespread industrial applications, was investigated. The experimental results confirmed stable levitation and clear resonance behaviour of the droplet. These findings demonstrate the effectiveness of the proposed non-contact surface tension measurement method that combines acoustic levitation with droplet vibration analysis. The present method is a promising approach for obtaining physical property data required for numerical analyses in industrial engineering fields, including ship engineering, and is expected to be extended to more practical liquids in future studies.

A 2 μL hexadecane droplet was acoustically levitated and exposed to a sweeping sound wave at 25 °C; as shown in Fig. 2, the projected area of the levitated droplet decreased at 121 Hz, and Fig. 3 indicates that the droplet is flattened at this frequency. Using Rayleigh's theory for the resonance frequency of an oscillating droplet, $\sigma = 1/8\ (2\pi f)^2\ \rho\ r^3$ (where f is the resonance frequency, σ is the surface tension, ρ is the density, and r is the droplet radius), the surface tension was calculated to be 26.56 mN/m, which shows excellent agreement with the literature value of 27.05 mN/m at 25 °C.

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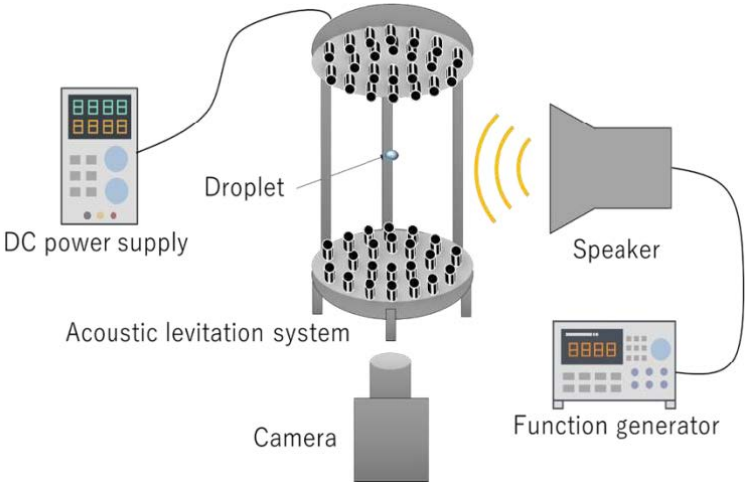


Figure 1. Schematic diagram of the experimental setup

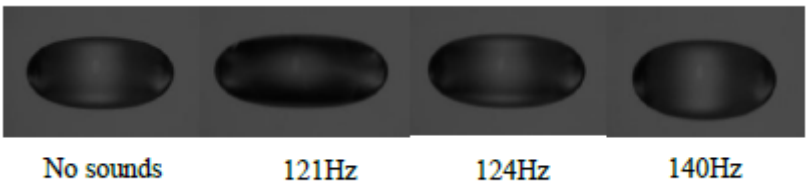


Figure 2. Droplet oscillation caused by sound waves from a speaker

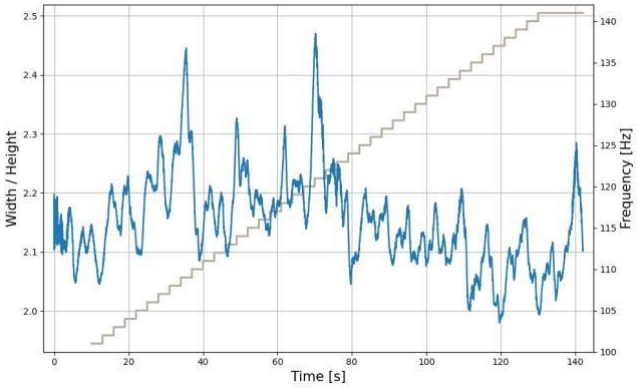


Figure 3. Transition of vertical pixels as frequency

Acknowledgements

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From Radar to Artificial Intelligence: Mapping Contemporary Technologies for Marine Oil Spill Detection

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Keywords: bibliometric analysis; marine environment; oil spill detection; contemporary technologies; TOPSIS

Oil spills remain a persistent and globally relevant threat to the marine environment, causing long-term ecological and economic impacts and requiring timely and reliable detection to enable effective response. Therefore, the development of modern technologies for the detection and analysis of oil spills is a key research and operational issue.

This study presents a systematic literature review and bibliometric analysis of contemporary technologies used for marine oil spill detection. The research is based on a structured search of the Web of Science Core Collection, resulting in the analysis of 63 relevant scientific publications published between 1993 and 2025. The selected studies focus on the development and application of advanced technologies for oil spill detection and modeling in marine and coastal environments, enabling the identification of dominant research trends and technological pathways.

To identify dominant research directions, a bibliometric network analysis was conducted using the VOSviewer tool. Analysis of keywords co-occurrence revealed six thematic clusters of applied technologies: radar and satellite systems (particularly SAR technology), optical and thermal infrared sensors, GIS and laser methods, spectroscopy, unmanned aerial vehicles (UAVs), and artificial intelligence and deep learning methods.

The results of the temporal analysis of keywords indicate a clear shift in research, from predominantly radar and engineering approaches to the integration of multi-sensor data, advanced image processing, and automated algorithms based on artificial intelligence. Additionally, the TOPSIS method of multi-criteria decision-making was used to rank scientific papers according to their relevance and topicality, using citation criteria and year of publication. This identified the most influential and recent papers shaping the current state and future development of research in oil spill detection. The analysis shows that optical sensors, GIS systems, and laser fluorescence are the most represented technologies in the reviewed works, while UAV platforms and advanced spectroscopic methods, although still less represented, are areas with significant development potential.

In conclusion, the results confirm that modern trends in oil spill detection are moving towards integrated, automated, and computer aided systems that enable faster, more accurate, and more reliable decision-making. Such an approach plays a key role in reducing the environmental and economic consequences of oil spills and highlights the need for global scientific and institutional cooperation to protect the marine environment.

Acknowledgements

This research was supported by the program contract of University of Split, Faculty of Maritime Studies with Ministry of Science, Education and Youth for the period 2025-2029. Project name: Artificial Intelligence Driving the Digital Transformation of the Maritime Sector - MareDiTrAI

State of Charge Estimation for Smart Buoy Battery Systems: Classical vs. Deep Learning Approach

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Keywords: smart buoy; state of charge; Coulomb counting; deep learning; energy management

Smart buoys are a key component of modern marine environmental monitoring and navigation safety systems, where reliable autonomous operation depends heavily on efficient energy management. As these systems typically operate off-grid and are subject to highly variable environmental conditions, accurate estimation of the battery state of charge (SoC) is essential to ensure long-term functionality, reliability, and optimal use of available energy resources.

This research paper aimed to investigate the potential for optimising energy consumption in smart buoys by applying deep learning. This was achieved by comparing the accuracy of battery SoC estimation using the classical Coulomb counting method and a deep learning-based approach. The analysis was conducted in the Matrix Laboratory (MATLAB) environment using three different operating regimes that represent variable energy generation and consumption conditions typical for smart buoys, including stable operation, reduced energy production, and increased load demand.

To ensure an objective comparison, both methods were evaluated under identical operating conditions, using the same input data, measurement noise characteristics, and reference SoC values obtained from an ideal mathematical battery model. The estimation accuracy of both the classical and deep learning-based approaches was assessed using the same performance metric, namely the Root Mean Squared Error (RMSE).

The results show that the deep learning-based method consistently achieves lower RMSE values across all analysed operating regimes compared to the classical approach. The performance advantage is particularly evident under conditions of variable and unstable energy production, where the classical method is more susceptible to accumulated estimation errors. These findings highlight the suitability of deep learning techniques for enhancing battery SoC estimation and overall energy management in smart buoy systems. The presented approach provides a solid foundation for future research involving real-world operational data and more advanced battery models in marine environments.

Acknowledgements

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Development of a Modular System for Monitoring Environmental Conditions in Shipboard and Simulation Environments

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Keywords: shipboard environmental monitoring; engine room conditions; noise level measurement; thermal environment; modular sensor system based on Power over Ethernet (PoE)

This paper addresses the development and application of a modular system for monitoring environmental conditions in a ship's engine room, on the bridge, and within a simulation environment. Particular emphasis is placed on the measurement and analysis of parameters such as noise level, air temperature, and relative humidity, which have a significant impact on the quality of the working environment, operational safety, and the long-term protection of crew health. Previous studies indicate that noise levels in ship engine rooms frequently exceed permissible limits, while unfavorable thermal conditions further exacerbate working conditions on board.

A distributed system of compact measurement modules equipped with sensors for monitoring relevant environmental parameters is developed. The modules are based on the Tinkerforge platform and are interconnected and powered using Power over Ethernet (PoE) technology, enabling reliable communication, centralized data acquisition, and straightforward integration into existing shipboard systems and ship simulators. The design of the sensor module enclosures is carried out using Autodesk Inventor CAD software, while their fabrication is realized through additive manufacturing technologies (3D printing), ensuring adaptability to various spatial and operational requirements.

The proposed system enables continuous and objective monitoring of environmental conditions in both real and simulated maritime environments and provides a foundation for assessing compliance with applicable international standards and recommendations. The results obtained can support improvements in ship space design, optimization of working conditions, and the development of modern educational and research methods in the field of maritime engineering and education.

Acknowledgements

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Navigating the Competency Void: Identifying Shortfalls between Maritime Training and Operating with Wind Assisted Propulsion Systems

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Keywords: wind assisted propulsion systems; WAPS; maritime education and training; MET; STCW; maritime competencies; maritime decarbonization

As the maritime sector navigates a complex transition toward net-zero emissions the application of Wind-Assisted Propulsion Systems (WAPS) has proven to be a highly effective solution for reducing fuel consumption and emissions. However, while these systems are being increasingly implemented on board, the educational background has not followed. This study examines the critical competency gap that has emerged between existing maritime education and the practical requirements of WAPS technology. By engaging maritime professionals through a targeted questionnaire, the research identifies specific knowledge gaps while accounting for the operational challenges and real-world experiences of seafarers.

The findings reveal that a lack of holistic understanding regarding vessel behavior is the primary obstacle to leveraging environmental conditions as an operational asset. To bridge this gap, integrated support from various disciplines is required. This research maps the essential areas that should be addressed through specialized additional training to ensure that the transition to green technology does not compromise operational effectiveness and safety.

Engine Operation Analysis During Normal and Misfire Conditions

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Keywords: diesel engine; cylinder misfire; numerical simulation; torsional vibrations

On large commercial vessels turbocharged two-stroke low-speed diesel engines are still nowadays the predominant choice for main propulsion units. Given their critical role, a thorough evaluation of engine behavior is essential not only under normal operating conditions but especially under abnormal conditions. These conditions may occur when one cylinder is out of operation and is classified strictly as an emergency situation. Nevertheless, modern engine designs anticipate such scenarios and provide operational guidelines defined by the manufacturer to ensure safe operation. This study investigates engine performance during a cylinder misfire condition, simulated by interrupting the fuel oil supply to a single cylinder. Numerical simulation of the MAN two-stroke slow-speed marine diesel engine has been performed to conduct the analysis. The simulation model was developed using SimulationX software. To support and partially validate the simulation results, two independent engine room simulators are additionally employed, offering complementary perspectives on system behavior. A detailed examination and comparison of operating parameters obtained from the simulation model and simulators provide valuable insights into engine performance, operational constraints, and permissible limits during cylinder misfire operation. Results provide insight into torsional vibration response of the main propulsion system, which is particularly significant under abnormal engine operating conditions. The findings improve understanding of emergency operating conditions and support safer decisions related to marine propulsion systems in general.

From Theory to Terminal

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Keywords: full mission simulator; student centered learning; maritime decarbonization

This project focuses on how a full mission ship simulator combined with a pedagogical approach to learning can prepare the maritime students for a maritime industry undergoing a paradigm shift driven by decarbonization encompassing a new level of complexity, digitally as well as technically.

The project is currently exploring how this technological infrastructure, combined with validated, student-centered learning methodologies, can form the foundation for future-ready competence development. At the core of the ongoing work is a transition from passive technical instruction toward active, experiential learning. By developing high-fidelity scenarios, the project aims to enable students to manage complex operations, ranging from the optimization of alternative fuel systems to safe maneuvering under extreme conditions.

The implementation process is anchored in experiential learning theory and problem-based learning. We are currently evaluating how these frameworks ensure a high transfer of learning, translating simulator-based skills into operational safety and environmental efficiency on board actual vessels.

For marine engineering students, the project is developing hands-on training modules focused on the technical intricacies of traditional as well as green propulsion systems. For nautical masters, the focus is on creating decision-making exercises that balance navigational safety with energy-efficient route planning. Through the iterative use of structured debriefing and formative assessment, the project seeks to ensure that future officers develop the critical mindset required to lead the global green transition.

This ongoing initiative indicates that the path toward green and safe maritime professionals requires a continuous synergy between advanced hardware and a deep pedagogical understanding of how humans learn and perform under pressure.

Using Comparative Importance Improvement Analysis Method for Navigation Competence Priority Mapping

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Keywords: bridge simulator; maritime education; CABA method; seafarer competence; dyadic perception

Maritime simulator training is embedded in Maritime Education and Training (MET) as a means of providing realistic environments for seafarer competence development. While learning analytics tools and techniques are well explored for typical lecture-based and online courses, their potential in maritime simulation training is rather underexplored. An effective maritime simulation training session usually involves three phases: pre-training briefing, simulation training task, and post-training debriefing. This study explores the use of Comparative Importance Improvement Analysis (CABA) method in developing a novel post-training debriefing learning analytics tool based on self-reported importance rating and improvement needs rating of 12 navigation competences for successful simulation task completion from student's and instructor's perspective. While students rate their own improvement needs for the task completion, instructors rate the students' overall improvement needs. Data was collected from six trainees and two instructors after completing a collision-avoidance simulation exercise in a Nordic maritime training institution. CABA method driven learning analytics visualization maps the 12 competencies in four quadrants which reveals misalignment between trainee self-perceptions and instructor judgments regarding their training needs. For instance, students perceive teamwork and leadership competence as low priority but when incorporating instructors' perspective in CABA analysis, teamwork and leadership competence appear in high priority quadrant. The proposed learning analytics visualizations based on the CABA method can be incorporated in learning analytics dashboards for new insights during post-simulation debriefing sessions.

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The Anatomy of Thermal Runaway Incidents in Battery Rooms of Electric Ships

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Keywords: electric ship; thermal runaway; battery room; post-incident analysis

The electric ships (ES) market is undergoing rapid transformation. According to Det Norske Veritas, the number of global ES surpassed 586 in 2022, representing approximately 56% of global green ships (DNV 2022). Retrofitting diesel-powered vessels with hybrid propulsion systems has also become a prominent trend in this transition. These alternative propulsion solutions are particularly relevant for inland ferries operating on shorter routes of under 100 nautical miles. Countries such as Norway and Denmark, both characterized by numerous inhabited islands, are leading the way in ordering and deploying ferries of this type.

Shipbuilders are increasingly adopting lithium-ion (Li-ion) batteries due to their high energy density. As is known, the higher the energy density, the higher the risk of uncontrolled energy flows. The major danger is thermal runaway (TR) that causes the battery to release very hot and flammable gases. The heat from the fire can cause more gas to be released, making the fire worse and hard to control (Yang et al. 2025).

Witnessed fires on four ES with Li-ion battery systems highlight unique safety hazards associated with these energy sources. While no one was heavily injured on these ships, the vessels sustained damage ranging from minimal to significant. Given that the operation of ES is still in the early stages, available data on their safety issues remain limited, and there is a lack of comprehensive risk analyses. With the increasing trend of ship electrification, the number of ES is expected to rise significantly, potentially exacerbating safety concerns.

For the analysis of TR incidents, we practice Accident Anatomy Analysis that combines both post-accident and predictive analyses (Callesen et al. 2019). The core of the method consists in the development of cause-consequence diagrams, which are a causal chain of events, states, and conditions following the initiating event.

The analyses provide a comprehensive overview of the sequential occurrence of the incidents, revealing their root causes, weaknesses in the control and management systems, and the design of the interfaces to enable early detection of critical faults, abnormal voltage fluctuations, temperature rise in battery cells, etc.

The method and the analysis will be demonstrated along with the findings for the improvement of incident detection, recommendations for orchestrated actions of the crew members, reduction of human error potential, and enhancement of the performance of the fire suppression system.

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Life Cycle Assessment of Electric Propulsion Ships Based on Empirical Operational Profiles

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Keywords: net-zero; electric propulsion ship; solar panel; battery; life cycle assessment

Achieving net-zero emissions in the maritime sector requires a systematic transition from conventional propulsion systems to low- and zero-emission alternatives supported by quantitative, operation-based assessments (Committee on Climate Change, 2019; DNV, 2023), while techno-economic and regulatory drivers continue to shape the competitiveness and adoption of decarbonization options for marine operators (Korberg et al., 2021; Mukherjee et al., 2023; Schinas and Stefanakos, 2012; Solakivi et al., 2022). This study analyzes the environmental impacts of transitioning to electric propulsion ships, focusing on their potential contribution toward net-zero shipping (Geertsma et al., 2017; Kistner et al., 2024; Park et al., 2022). A case study is conducted on a vessel operated by a shipping company in the Republic of Korea, using real-world operational data to ensure practical applicability and robustness of the analysis. Based on actual vessel operational profiles, a detailed electric propulsion system model is developed to estimate electricity consumption under realistic operating conditions, as Figure 1 (Geertsma et al., 2017; Kistner et al., 2024). In addition, a solar photovoltaic (PV) generation model is established using real sailing routes and time-dependent solar irradiance data, enabling the simulation of onboard renewable energy production (McAllister and Wang, 2024; Park et al., 2022).

A simulation-based life cycle assessment (LCA) is then conducted to evaluate environmental impacts across three comparative scenarios: (1) a conventional propulsion ship, (2) an electric propulsion ship, and (3) an electric propulsion ship integrated with onboard solar photovoltaic panels (Park et al., 2022). The assessment adopts a full life-cycle perspective, capturing energy supply, operational electricity consumption, and associated greenhouse gas emissions, with PV life-cycle inventory assumptions informed by updated solar PV LCA literature (Smith et al., 2024).

The results quantitatively demonstrate the extent to which electric propulsion systems reduce environmental impacts compared to conventional propulsion and further reveal the additional mitigation potential achieved through renewable energy integration (McAllister and Wang, 2024; Park et al., 2022). This study provides data-driven insights into the role of electric propulsion systems in advancing net-zero shipping and offers practical guidance for shipping companies and policymakers considering the deployment of electric and hybrid-electric vessels (DNV, 2023; Geertsma et al., 2017; Kistner et al., 2024).

Beyond environmental performance, the transition to electric propulsion introduces distinct operational characteristics and safety considerations compared to conventional fossil-fuel systems (Geertsma et al., 2017; Kistner et al., 2024). Therefore, this study further identifies key safety and operational training requirements specific to electric propulsion and renewable-integrated systems to support their safe and effective deployment.

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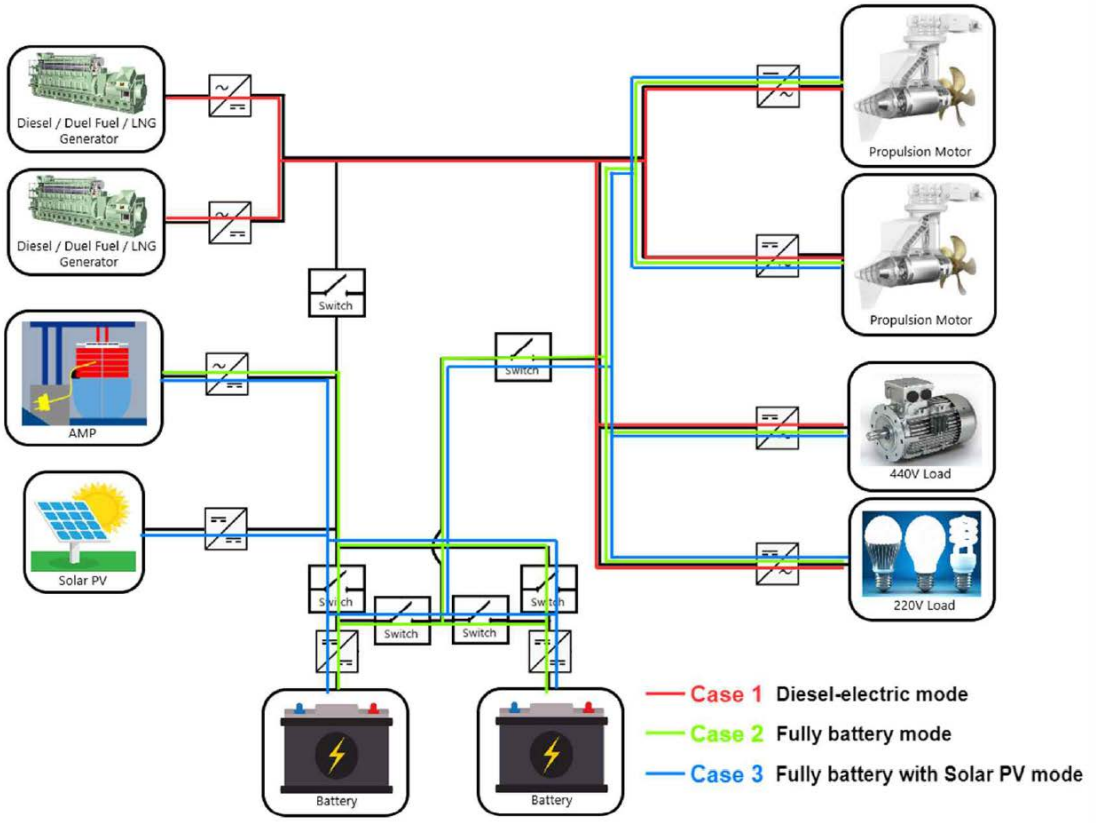


Figure 1. Concept design scenarios for a case ship

LetsROC – Human-Centred Validation of Remote Operation Centers for Maritime Autonomous Surface Ships

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Keywords: remote operation centers; maritime autonomous surface ships; human-centred design; human factors validation; maritime simulation; operator training; human machine interface

Maritime Autonomous Surface Ships (MASS) promise enhanced safety and operational efficiency through remote operation from shore-based Remote Operation Centers (ROCs). However, critical gaps persist between technological capability and human-centred operational reality. The IMO's draft MASS Code mandates human-centred design and operator competency frameworks but lacks empirical evidence supporting specific requirements. ROC operations present fundamentally different challenges from traditional bridge watchkeeping: managing attention across multiple vessels, maintaining situational awareness through mediated sensor data, and appropriate workload distribution between human operators and autonomous systems. Research demonstrates ROC operators face increased cognitive demands during decision-making phases despite reduced physical task execution, with risks of information overload and vigilance decrements requiring systematic validation. The LetsROC project addresses these challenges through systematic ROC development and human factors validation.

LetsROC aims at delivering validated ROC-HMI (Human Machine Interface) design principles, evidence-based Standard Operating Procedures and competency frameworks addressing MASS Code requirements. To achieve this outcome, LetsROC employs stakeholder requirements analysis through workshops with shipping companies, regulators, and operational personnel. The objective is to develop ROC-HMI which is aligned with MASS Code principles. Therefore, essential ship parameters are identified and integrated into the ROC platform through the connection to the ship simulators. This will enable realistic testing under controlled conditions and comprehensive three-phase empirical validation. LetsROC's empirical findings are expected to provide data on human performance boundaries essential for determining safe manning levels and operational envelope definitions. It will also provide validation protocols, simulator-based assessment methodologies, and competency frameworks that are foundations for future curriculum development.

Acknowledgements

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Intelligent Anti-collision System for Unmanned Surface Vessels Based on Short-Range 3D Automotive Radar

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Keywords: unmanned surface vessel; intelligent system; anti-collision; 3D automotive radar

Unmanned surface vehicles (USV) have become extremely popular in recent years in both the civilian and military sectors. One of the fundamental problems of unmanned vessel navigation is safe anti-collision maneuvering. One solution is to use short-range automotive radar. Due to the small size of the vessel and the very short target tracking time, it is necessary to use high-performance tracking algorithms, maneuver development, and anti-collision control.

Very promising results of radar tracking in conditions of maneuvering vessels and very short observation times of measurement series—training sequences of an artificial neural network—were obtained using a General Regression Neural Network (GRNN) (Stateczny 2002; Stateczny and Kazimierski 2008).

The experiments were conducted in real-world conditions using a 3D automotive radar sensor mounted on a USV vehicle called HydroDron-1. Experiments with the HydroDron-1 vehicle and 3D automotive radar are presented in publications (Stateczny et al 2019a and 2019b).

The anti-collision intelligent algorithm is based on a supervised MLP (Multilayer Perceptron) neural network trained via imitation learning from solutions generated by a deterministic algorithm. The deterministic anti-collision algorithm uses a set of candidate trajectories in the process of calculating a safe maneuver or a safe trajectory (Lazarowska 2017, 2022).

The USV speed test is based on a linear matrix inequality (LMI) controller. Work on the trajectory focused on optimising the objective function based on minimizing two norms. The H2 norm related to optimising the energy required for USV operation. The second Hinf norm responsible for minimizing the deviation of the tested system. Artificial intelligence was introduced into the research, namely the PSO algorithm based on swarm particles, which adapts the objective function to the synthesis of a multidimensional LMI controller (Koznowski et al. 2023; Rybczak 2018; Sturm 1999)

The article presents aspects of the use of artificial intelligence methods in the process of short-range automotive radar signal processing and anti-collision maneuvering tested on HydroDron-1 (picture 1).

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Figure 1. USV HydroDron-1 during measurements in the port of Gdynia.

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Evolution of Remote-Control Technologies for Maritime Autonomy: A Patent-Based Technology Mapping and Forecasting Analysis

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Keywords: maritime autonomous surface ships; remote-control technologies; patent analysis; technology forecasting; BERTopic

Remote-control technologies are transforming maritime operations, enabling shore-based vessel management and paving the way toward higher degrees of autonomy. Despite growing innovation in areas such as propulsion systems, navigation interfaces, and communication infrastructures (Ivanova et al., 2021; Burmeister et al., 2020), there remains a significant gap in understanding how these technologies interconnect as an integrated ecosystem and which specific areas will drive future innovation. While existing literature has examined individual technological components, less attention has been paid to mapping the entire technology landscape and forecasting development trajectories. This research addresses three core questions: (1) What are the key technology clusters in maritime remote-control systems? (2) How do these technologies interconnect within the innovation ecosystem? (3) What is their relative maturity and potential future trajectory? Patents offer unique insights into technological evolution, as roughly 70-90% of technological information in patent documents is not published elsewhere (Asche, 2017).

A comprehensive dataset of 1,875 patents (2010-2024) was collected from Google Patents using a systematic search query focusing on remote-control technologies in maritime contexts (Belabyad et al., 2026). The analytical framework (in line with Belabyad et al. (2025)) integrates four methodological components: (1) bibliometric analysis examining temporal trends, geographic distribution, and key assignees, (2) BERTopic modelling for automated topic extraction and technology categorisation, (3) network analysis to quantify technological relationships and identify bridging technologies, and (4) Bass diffusion modelling parameterised by network centrality to assess technology maturity and forecast development trajectories to 2033.

The analysis identified eight main technology categories encompassing 30 subcategories. Network analysis revealed "Route Planning & Optimisation" as the most connected technology while "Safety Monitoring & Alerting" had the highest eigenvector centrality, indicating strong connections to other influential technologies. Moreover, several technologies including "Human-Autonomous Interaction" and "Emergency Response Systems" appeared isolated in the network, suggesting development gaps requiring integration attention.

The maturity assessment shows that maritime remote-control technology remains in active development, with 65.5% of technologies in the growth stage and 34.5% in the emerging stage. None have reached maturity or saturation phases. Forecasting results indicate significant expansion potential through 2033, with "Remote-Control Systems" projected to grow from 765 to 1,640 patents, and "Autonomous Operation" technologies showing steep projected growth despite relatively few current patents.

This research provides useful insights for stakeholders. For industry practitioners, the identification of bridging technologies and integration gaps informs strategic technology investment decisions. For policymakers and standardisation bodies, the technology maturity assessment highlights areas requiring regulatory attention.

For maritime education institutions, the findings highlight emerging competency requirements in hybrid human-machine operations. The isolation of "Human-Autonomous Interaction" technologies presents a particular concern for maritime safety, suggesting urgent need for integration initiatives to ensure effective human oversight during the transition to more autonomous operations.

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Hardware-in-the-Loop-Based Research Framework for Renewable-Based Shipboard Power Systems

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Keywords: hardware-in-the-loop (HIL); shipboard microgrids; renewable energy sources (RES)

Shipboard electrical power systems typically operate as isolated microgrids, integrating diverse electricity generation units and loads into a unified and controllable energy system. As the maritime sector intensifies efforts to reduce greenhouse gas emissions, the integration of renewable energy sources (RES) into shipboard electrical infrastructures represents a significant transition from conventional fossil-fuel-based operation toward more sustainable solutions.

However, the integration of RES, variable-speed drives, battery energy storage systems, digital protection relays, and other power-electronics-interfaced subsystems into modern shipboard energy systems introduces substantial technical challenges. The direct coupling of renewables sources and converter-based technologies results in pronounced nonlinear dynamics and complex subsystem interactions, making real-world testing extremely costly and time consuming, especially for large-scale maritime applications. Similar obstacles arise in system lifecycle maintenance for system upgrades and updates, where modifications to operational vessels are complex and costly.

To address these challenges, this paper presents a high-fidelity Hardware-in-the-Loop (HIL) framework tailored for shipboard microgrid validation under real-time constraints. A crucial requirement for a successful HIL implementation is ultra-high fidelity simulation of shipboard electrical systems supported by appropriate software and hardware platforms capable of accurately replicating real devices and physical processes. Only under such conditions can the full benefits of testing in a controlled environment be achieved. This is particularly important for assessing interoperability among individual shipboard electrical subsystems and for comprehensive validation of the integrated power system.

The framework further incorporates Controller Hardware-in-the-Loop (C-HIL), allowing physical digital controllers and protection relays to interface with the real-time simulator via low-latency analog and digital I/O. This configuration enables closed-loop validation of advanced converter control architectures, including grid-forming and grid-following strategies for low-inertia shipboard microgrids, as well as coordinated energy management and supervisory control algorithms. Integration with a Rapid Prototyping environment facilitates iterative controller tuning and performance benchmarking without risks associated with onboard deployment.

Several case studies are presented for both AC and DC shipboard microgrid configurations, focusing on: harmonic distortion mitigation caused by nonlinear loads; stable RES integration in low-inertia environments, and maximum power extraction from photovoltaic (PV) systems under partial shading conditions.

Quantitative results demonstrate that the proposed HIL methodology enables accurate prediction of harmonic spectra, dynamic stability boundaries, and cross-coupling effects between subsystems. Moreover, advanced converter control strategies validated within the C-HIL environment significantly enhance RES utilization and DC-link voltage stability while maintaining compliance with maritime power quality constraints.

Phrasal Verbs at Sea: Why They Are Essential for Safe and Effective Communication

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Keywords: maritime English; phrasal verbs; SMCP; standardization; maritime safety

This paper examines the role of phrasal verbs in Maritime English by combining a qualitative corpus analysis of Boris Pritchard's Ship's Business in English (2002) with survey data from fifty-six active seafarers. While previous research has focused on standardized IMO communication phrases, the research gap concerns the persistent use of phrasal verbs in authentic shipboard communication and the tension between regulatory requirements and actual language practices. To address this gap, the study employed a mixed-methods approach: a corpus analysis involving identification and categorization of phrasal verbs, alongside a survey analysed using descriptive statistics, including frequency distribution and percentage calculations. Although international regulations, particularly the IMO's Standard Marine Communication Phrases, require standardized language and prohibit alternative expressions, the findings reveal that phrasal verbs remain indispensable to authentic shipboard communication. This persistence suggests a gap between prescribed norms and linguistic realities at sea. A significant majority of respondents reported using them frequently or constantly. Statistical analysis indicates that expressions such as make fast, run out, veer out, fire up, back down, muster at, and alter the course are highly prevalent in daily operations, occurring in up to 92% of analysed cases. The paper argues that while standardization is essential for safety, phrasal verbs cannot be replaced by alternative phrasing; instead, they must be systematically taught within a task-based Maritime English pedagogy to ensure genuine communicative competence and operational safety. Addressing this discrepancy between formal requirements and authentic language use is therefore critical to both effective training and the prevention of miscommunication on board.

Development and Validation of a Harmonized Methodology for Passive Acoustic Underwater Noise Monitoring Using Marine Robotics: A Pilot Study

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Keywords: underwater noise monitoring; pilot actions; marine robotic system

This study presents a methodology for underwater noise monitoring that integrates marine robotics with passive acoustic systems. The approach is intended to provide consistent, coherent, and transferable results across different marine environments and operational contexts. The methodology covers all key phases of underwater noise assessment: preparation, field application, monitoring, and evaluation. Its applicability was tested through pilot studies in three areas of the Adriatic Sea (Croatia, Bosnia and Herzegovina, and Montenegro). The results demonstrate the potential of a standardized, robotically supported monitoring framework to improve the spatial and temporal coverage, comparability, and reliability of underwater noise measurements. During the pilot preparation phase, specific micro-locations were selected, including urban coastal areas, beaches, mariculture zones, maritime traffic corridors, and nautical ports. For each micro-location, a target monitoring area was defined, the seabed and water column were characterized, and the operational monitoring depth was determined. Underwater noise was recorded using μRudar passive acoustic monitoring hydrophones deployed at all micro-sites. Pilot actions were conducted during two seasonal periods to capture variability: a high-frequency period during the nautical season (spring–autumn) and a low-frequency period during the off-season (winter). Standardized data recording procedures and unified protocols for marine robotics ensured consistency and comparability across sites. All recorded data are analyzed using the SpectraDAQ-200 data acquisition system and SpectraPLUS software, and results were compared across pilot sites and seasonal intervals to identify trends and anomalies.

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Bridge Watch Levels and Watchkeeping Standards for Remotely Operated Vessels: Identification of Operational and Regulatory Gaps and Challenges

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Keywords: bridge watch levels; remotely operated vessels; human error; autonomous ships

Although shipping accidents in general are often caused by a chain reaction of various factors, it has been proven that humans contribute directly or indirectly to over 70–80% of accidents at sea (Sánchez-Beaskoetxea et al., 2021). To mitigate the impact of human error, the International Maritime Organization (IMO) has developed guidelines for best practices and requirements for safe watchkeeping (IMO Resolution A.285, 1973).

In this context, the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) sets out international standards for the training, certification and watchkeeping of seafarers, including navigational watchkeeping arrangements and responsibilities. Additionally, the International Chamber of Shipping (ICS) Bridge Procedures Guide is widely used as industry best practice for bridge watchkeeping, personnel responsibilities, and collision avoidance procedures (ICS, 2022).

However, with the increasing implementation of automation and the introduction of remotely operated vessels (ROVs), the applicability of conventional watchkeeping standards becomes uncertain. Although the IMO has defined different degrees of autonomy for Maritime Autonomous Surface Ships (MASS), current guidance documents, including the Interim Guidelines for MASS trials and the Outcome of the regulatory scoping exercise, do not specify watchkeeping standards or bridge watch levels of these types of vessels (Interim Guidelines for Mass Trials - MSC.1/Circ.1604, 2019; Outcome of the Regulatory Scoping Exercise for the Use of Maritime Autonomous Surface Ships (MASS) - MSC.1/Circ.1638, 2021). Mentioned regulatory gap exists despite the fact that remotely operated vessels are already in operation and are expected to increase in number in the future.

As a part of shipping operational stand standards, the Bridge Watch Levels (BWL) are included in the Safety Management System (SMS), which is an essential tool for safe operation at sea and aims to reduce the possibility of human error in bridge procedures. In view of the implementation of automation onboard, and in particular the introduction of ROVs, the above standards should be considered for adaptation to the new requirements of the shipping industry.

For this reason, the aim of this research is to analyze the potential risks arising from the absence of dedicated guidelines for general watchkeeping and bridge watch level definition for ROVs, as the most recent and unconventional segment of maritime transport. In order to achieve this, standards for safe watchkeeping focusing on defined BWLs from SMS documents of several shipping companies were first examined and compared, considering important technical factors such as ship dimensions, ship type, and minimum safe manning. The gathered data were then correlated with corresponding operational characteristics of ROVs in order to identify operational gaps and establish a foundation for the future development of watchkeeping guidance specifically tailored to remotely operated vessels.

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Navigating Uncertain Futures: Digitalization, Green Transition, and Maritime Education

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Keywords: maritime education; technological transformation; digitalization; philosophy of technology

In recent discussions on the green transition of the maritime industry, it is often emphasized that the critical challenge lies not only in technological development, but also in the implementation of the technological change onboard. IMO and EU regulations push the maritime sector to adopt new technologies at a fast pace. It is therefore crucial that the new technologies and digital tools are tested and adopted in practice by end users and in this case by seafarers. However, previous studies show negative attitudes towards implementing digitalization in ports and onboard ships; also, significant resources are needed for the adoption process. This, in turn, places clear demands on education, training, and motivation. It remains unclear what kind of attitude towards new technologies is most beneficial for the education of seafarers and engineers, as technological advancements often introduce new challenges for those who work with them. We suggest that maritime education should explicitly engage with these challenges rather than overlook or downplay them.

Regarding digitalization, human-centred digital information can support environmentally efficient navigation and informed decision-making, thereby contributing to maritime safety and sustainability. At the same time, such systems may distance operators from the lived, experiential reality of the sea and foster an illusion of control and security. Excessive reliance on digital systems can increase vulnerability when technologies fail or become unavailable, thus revealing the ambivalent character of digital tools in maritime practice.

In his philosophy of technology, Bernard Stiegler describes this ambivalence not as a flaw of a particular technology, but as a structural feature of all technology. He uses the ancient Greek word pharmakon to emphasize the ambivalent nature of technology: it is both remedy and poison. While offering new solutions, innovative technology also introduces new challenges that must be taken into account. This should by no means be understood as technocriticism. Rather, this philosophical insight is crucial for identifying two harmful attitudes towards technology: resistance to technological change in favor of established practices on the one hand, and uncritical faith in a particular technology as the sole solution to environmental crisis on the other. Both attitudes overlook the fundamentally dynamic character of technological transformation.

Our suggestion is that maritime education should focus not only on specific new technologies alone, but on preparing future maritime professionals to navigate continuous technological change and uncertainty. The unforeseeability and uncertainty of the future does not imply inevitable failure of the green transition; on the contrary, it highlights the openness of possibilities.



Economic Topics

Smart and Sustainable Marinas: Digital Transformation, Digital Competencies and Organizational Performance

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Keywords: marina management; digital solutions; digital competencies; business performance; sustainable nautical tourism

The marina and recreational boating sector is undergoing digital transformation in response to evolving customer expectations, increased competition, environmental challenges, and technological advancements. Digital solutions increasingly support integrated and sustainable marina operations through real-time berth tracking, automated contract management, predictive maintenance, analytics, and environmental monitoring. However, limited research examines how digital transformation across marina operational domains influences multidimensional marina performance outcomes, including financial, customer, internal process, safety, innovation, growth, and environmental dimensions. This study proposes a framework connecting digital solutions, digital competencies, training and education, marina performance outcomes, and the main enablers and constraints of digital transformation. The research employs a qualitative approach based on secondary qualitative analysis and in-depth interviews with marina professionals from operations, management, engineering, digital systems and IT support, administration, safety, marketing, and environmental management. Findings indicate that digital transformation significantly influences marina performance outcomes, while its effectiveness increasingly depends on digital competencies, continuous training and education, organizational readiness, and sustainability-oriented operational practices. The proposed framework contributes to smart marina and sustainable nautical tourism literature by integrating digital solutions and transformation, competencies, and multidimensional marina performance outcomes within a single conceptual structure. The findings provide practical implications for marina managers, policymakers, educators, and training providers.

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The Impact of the Post-COVID World on the Containerized Cargo Turnover in the East Mediterranean and Black Sea Area

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Keywords: containerized cargo turnover; East Mediterranean and Black Sea area; Red Sea and Black Sea crisis

When COVID-19 was coming to an end in the beginning of 2022, all humanity was hoping that life would come back to normal and world would continue its steady development. Unfortunately, several military conflicts, as well as turbulent political events have pushed the still fragile world economy into new and bigger challenges, the effect of which has been even more evident in the area of East Mediterranean Sea and Black Sea.

The first major turmoil was the unpredicted Russian-Ukrainian conflict which is still shaping the sea trade environment of the region. The frequent reports of sea mines floating in the Black Sea waters, together with recent events of drone attacks on ships believed to be part of Russian shadow fleet, have made seaborne cargo turnover to the neighboring countries drop significantly, instead of the hoped post-COVID increase. The combination of the high-risk visits of the Black Sea, together with ever growing expenses for entering the area, makes operators further reluctant to trade in these particular seas. The problem is still far away from the solution all Black Sea countries have been hoping for.

The second major event was the unprecedented attack on Israel on behalf of the Hamas movement, leading to the eruption of a major Gaza war and the Red Sea crisis. (Pedrozo 2025) The Red Sea crisis is the name adopted for the military actions of the radical Islamic group of the Ansar Allah, also known as Houthis, in solidarity with Palestinian people in Gaza. As a result, all seaborne trading endeavors believed to be in some way connected to Israel have been attacked. According to official statistical data, almost 100 vessels have fallen victims to Houthis' action, which involve hijacking (like the case of m/v Galaxy Leader) and even drone attacks which eventually have sunk 4 ships. The determination of the attacks leads to withdrawal of most seaborne carriers from the Red Sea and Suez route. As a result, most port calls in the East Mediterranean area have dropped significantly (Delivorias 2024). The shipments were reorganized to go through the cape of Good Hope, and despite significantly higher rates and longer transit times, trade found its way to expand in Western part of the continent, leaving most transshipment hub in the East without significant trade.

The Black Sea region was further affected by the rise of Istanbul/Bosporus and Dardanelles traffic charges, increased by 15% by July 1 2025. This event, together with the already hostile environment of the Black Sea has additionally contributed to the sharp drop of seaborne cargo turnover in the area (Yetkili et al. 2015).

The present research aims to analyze the main trading routes in the East Mediterranean Sea, giving the idea on how the global politics has affected the shipping industry, particularly in the container trade. By analyzing statistical data of cargo turnover and vessel traffic, we examine the main factors with biggest impact and the counteractions of the industry in its effort to keep the trading routes and the additional shipping services, still active. For the purposes of the study, specialized software (VesselFinder) is used to track and analyze vessel traffic. Using its built-in functions for playback (Player) and analysis (Voyage Analyser), an archive of containerized cargo traffic for the last 3 years in the area of interest has been processed and analyzed. (Figure1).

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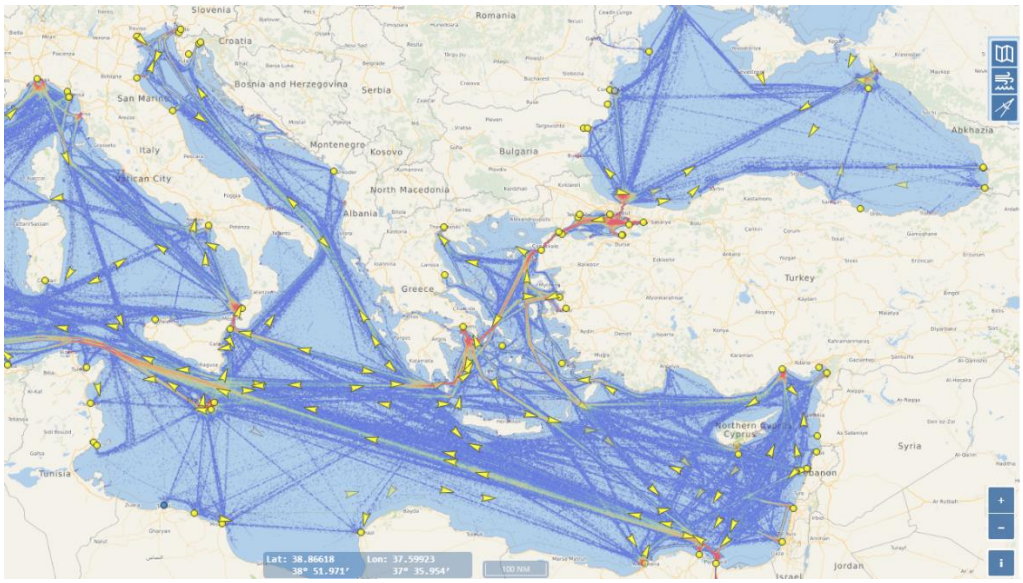


Figure 1. A screenshot of Voyage Analyser application used to analyze the traffic of containerships in the area of interest.

Economic and Technical Assessment of Modern Wind-Assisted Propulsion Systems in Maritime Cargo Transport

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Keywords: wind-assisted propulsion; maritime cargo transport; economic efficiency; hybrid propulsion systems; sustainable shipping

Increasing environmental regulations and rising operational costs have renewed interest in wind-assisted propulsion technologies within the maritime sector. This study examines the economic feasibility of implementing modern wind-assisted systems on cargo vessels, while also considering technical performance and integration requirements. The research focuses on the potential of various solutions, including aerodynamic sails, rotor-based devices, and other hybrid propulsion aids, to partially replace conventional fuel-powered engines.

A comparative approach is applied, evaluating hybrid configurations against vessels operating solely on traditional energy sources. The analysis considers operational cost structure, potential fuel savings, maintenance requirements, and equipment placement constraints, emphasizing realistic application scenarios. Technical parameters are integrated with economic considerations to ensure that the assessment reflects both engineering practicality and financial viability.

Results suggest that wind-assisted technologies can provide measurable economic benefits under certain operational and navigational conditions, while simultaneously contributing to environmental sustainability objectives. A combined technical and economic evaluation demonstrates the practical potential of these systems for commercial shipping and highlights the role of wind energy as a viable supplement or alternative to conventional propulsion.

The study emphasizes that integrating wind-assisted solutions supports long-term strategic goals in maritime transport, particularly in achieving more sustainable and efficient cargo operations. These findings offer a foundation for further development and wider adoption of hybrid propulsion technologies in the maritime industry.

Food Service Quality as a Human-centred Operational Indicator in Maritime Training Vessels

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Keywords: food acceptance; service quality assessment; onboard operations; operational performance measurement; human-centred maritime education

Ensuring high-quality food provision on maritime training vessels is a critical component of the onboard operational support system. While catering is often treated as a mere logistical necessity, its quality profoundly influences cadets' well-being and psycho-physical functioning within the demanding maritime environment. Observed discrepancies between the offered food services and cadets' expectations can lead to reduced catering utilization and inefficiencies in resource management, which directly affects the sustainability of shipboard operations.

The aim of this study is to examine whether perceived food service quality can serve as an operationally relevant indicator that reflects the alignment between support processes and user needs. Adopting a human-centred perspective, the research positions perceived service quality as a measurable proxy for evaluating key dimensions of operational performance in a maritime education context.

The analysis is based on a questionnaire survey conducted among maritime cadets, including both those who have completed sea practice and those preparing for their first voyage. The research instrument employs descriptive response scales to assess perceived food service quality, frequency of meal avoidance, and organizational determinants such as choice availability, predictability, and timing. Furthermore, it evaluates the perceived impact of nutrition on concentration and daily functioning, which is essential for educating safe maritime professionals.

Supplementary consultations with nutrition specialists provide a contextual interpretation of generational dietary patterns and feasible nutritional solutions within shipboard constraints. The findings are intended to support the development of best practices in food service management, improve resource planning, and promote waste reduction, aligning with the goals of educating green maritime professionals. Ultimately, the study demonstrates that food-related service quality functions as an operationally meaningful indicator within maritime training vessel management systems.

KPI Framework for Evaluating the Finnish Maritime Single Window, NEMO

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Keywords: Europe; maritime single window; NEMO; ports

The International Maritime Organization (IMO) has laid the groundwork for many digitalization processes through treaties. IMO has adopted a treaty requiring all IMO Member States to have a "Maritime Single Window" (MSW) for ship port calls. MSWs are single, centralized data platforms for collecting and exchanging information on ships' arrivals, stays, and departures (International Maritime Organization 2024).

In the European Union (2019), under the IMO treaty, an obligatory regulation on the European Maritime Single Window environment (EMSWe) has been in force for all member states. The Finnish Maritime Single Window under EMSWe is called NEMO and will be fully operational in 2027 (Fintraffic n.d-a). NEMO's process development has been studied in "NEMO CEF" project at Satakunta University of Applied Sciences. Key aspects of the NEMO process development have been different stakeholders, their expectations, change management processes (such as Kotter's (n.d-a) eight steps of change), skills development needs, and the tools for skills development. Sustainability has been a horizontal theme of the process development. Sustainability can be defined as the triple bottom line: the foundation of a successful business is the environmental health of the planet, which improves people's well-being and also generates profit (Elkington 1997).

The aims were to evaluate the implementation and outcomes of three pilot cases and assess their impact on data sharing and stakeholder change management processes. The study consisted of defining the pilot shipping cases, setting up the pilot cases, analyzing the stakeholders involved, their change management processes, and the key performance indicators (KPIs).

The selected pilot shipping cases were 1) Finland-Finland: cargo type: bulk, container, 2) From/to EU to Finland: cargo type: bulk, containers, combined (goods and people), 3) From/to outside EU: 3rd countries to Finland: cargo type: bulk, containers. The stakeholders were categorized using the power interest matrix into 1) Key players, who have high power and high interest, 2) Context setters, who have high power but lower interest, 3) Subjects who have a high interest but low power, and 4) the crowd, with low power and interest.

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Safety-Oriented Approach to Shipping Development Based on Quality Management of Technical Operation of a Vessel

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Keywords: management; safety shipping; development; efficiency

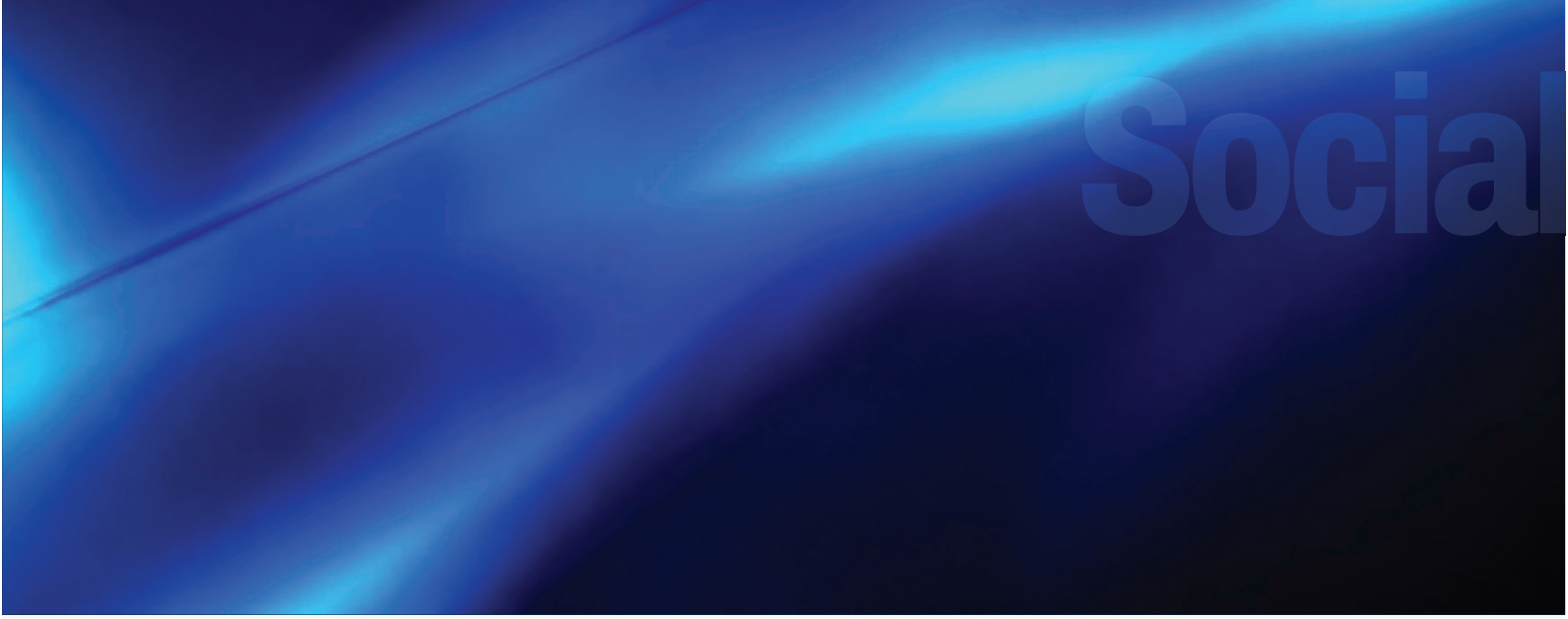
Transport and communications constitute one of the fundamental sectors of any national economy. Maritime transport as a cornerstone of global trade ensures international economic relations and contributes significantly to the economic and national security of states.

Economic security represents a key component of systemic safety in shipping. It is closely linked to maritime safety, defined as the protection of human life and health, the marine environment and property against unacceptable risks of accidents, injuries, environmental damage or material loss. This concept is enshrined in international standards – primarily the International Safety Management (ISM) Code – and national regulations governing the safety management system for sea and river transport.

The systemic safety of shipping has a complex multi-level structure. Its effective functioning depends heavily on the technical condition of vessels and the reliable operation of ship equipment and mechanisms. Consequently, modern inspection and maintenance practices are essential for implementing a safety-oriented approach to shipping development.

The aim of this study is to examine a safety-oriented approach to the development of world shipping through effective quality management of technical vessel operations. The research analyses scientific publications to identify key interrelated issues in safety-oriented shipping development and quality management systems for vessel technical operation. It examines the concept of a multi-level shipping safety system and substantiates the economic rationale for studying the theoretical foundations of quality management in ship technical operations.

Drawing on international and national standards, the study clarifies the terms "safety orientation," "multi-level safety system," "quality management" and "quality management system." It establishes the theoretical foundations and functional elements of ship technical operation systems and formulates a model of a safety-oriented approach to shipping development that integrates multi-level safety principles with a quality management system.



Social Topics

Towards a Human-Centred Framework for AI-Based Maritime Training Implementation: Evidence from a PRISMA Review

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Keywords: first Maritime Education and Training (MET); Artificial Intelligence (AI); Technology Adoption; Critical Success Factors (CSF); Implementation Challenges

AI technologies have enhanced maritime education and training through the personalisation of learning content (Karimi et al., 2024; Ibrahim, 2024), personalised and real-time performance feedback (Markopoulos et al., 2022; Lall & Liu, 2025; Karimi et al., 2024), and immersive (Miyusov et al., 2022) and adaptive practice environments (Bartusevičienė & Valionienė, 2021). However, despite the growing interest in AI applications within Maritime Education and Training (MET), the adoption of these solutions in real-world settings continues to face significant constraints, largely due to the safety-critical nature of the sector and the need to ensure reliability (Ibrahim, 2024), pedagogical validity (Bogusławski et al., 2022), and alignment with certification requirements (Vukelic et al., 2023; Lall & Liu, 2025).

Although relevant reviews exist, the evidence remains dispersed and fragmented across technologies and methods. Some reviews address the use of digital tools in human resource development within the maritime sector (e.g., LMS, VR, AR and AI), offering an overarching perspective on trends and challenges, but without examining in depth the mechanisms and practical conditions that underpin AI implementation (Autsadee et al., 2023; Vukelic et al., 2023). Others focus on adaptive instructional systems and intelligent tutoring systems (AIS/ITS) applied to maritime safety training, identifying AI/ML techniques and limitations such as data scarcity and difficulties in collecting data from real scenarios, yet restricting the analysis to this specific instructional subdomain (Karimi et al., 2024). None of these approaches adequately addresses the practical question of what hinders and what enables the implementation of AI in maritime training in real-world contexts, particularly given the distinct requirements of MET institutions and maritime industry organisations.

Therefore, a critical gap remains: there is a lack of an implementation-oriented integrative review that systematically synthesises, across contexts, what prevents and what enables the scaling of AI solutions in real maritime training (both MET institutions and industry). This study proposes a systematic review following PRISMA, analysing 36 peer-reviewed articles (2016–2026) to identify barriers and critical success factors (CSFs), including data governance, validation, technological maturity, certification requirements, and operational feasibility. As an outcome, the study will propose an actionable framework linking barriers, enablers, and recommended actions, supporting sustainable strategies for AI adoption in MET.

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Interference of Croatian as the Mother Tongue among ESP students

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Keywords: EFL; ESP; maritime English; Croatian students; mother tongue interference

Learning English as a Foreign Language (EFL) presents various challenges for Croatian learners, including the students attending Maritime English (ME) classes at the Faculty of Maritime Studies in Split. Due to significant differences between Croatian and English grammar rules, students often tend to make systematic errors that affect their overall language skills and may eventually affect communication, safety of navigation, efficiency and daily operations in various branches of the maritime industry in which they intend to pursue careers.

The study was conducted through a mixed-methods approach. Empirical methods, such as surveys, testing, assignments, video / live presentations and in-class activities were used in order to identify and clarify the errors resulting from negative mother tongue interference. The methodology then included qualitative data analysis, i.e., observational, cognitive and comparative approaches focusing on lexicosemantic and grammatical features of Croatian and English, and their mutual influence in the language learning process. Contrastive analysis was particularly useful in highlighting the key pronunciation, spelling, grammar and vocabulary areas where Croatian students make common errors.

It is essential for ME educators – especially those at maritime schools – to identify and understand these errors in order to develop effective strategies that address specific learner needs. Understanding these challenges and addressing the errors through targeted teaching tools (focused practice, contrastive analysis and clear explanations) can prevent or mitigate negative mother tongue transfer and significantly improve students' accuracy, fluency and confidence in English communication.

A Framework for Evaluating STCW Refresher Training Effectiveness and Seafarer Recovery

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Keywords: STCW refresher training; seafarer fatigue; shore leave recovery; online/hybrid training; maritime policy

The STCW Convention mandates refresher training to ensure seafarers' continued competence in safety-critical skills. In parallel, shipping companies increasingly require additional non-STCW internal training, often delivered through digital platforms. While these developments aim to strengthen compliance and safety, concerns are growing that training obligations, particularly when scheduled during shore leave, may affect recovery, increase fatigue, negatively affect quality of life and increase financial burden. Despite the regulatory importance of these challenges, systematic evidence capturing both training effectiveness and welfare impacts remains limited. This paper presents the development of a structured, questionnaire-based research framework designed to evaluate the effectiveness of STCW refresher training alongside the impact of STCW and non-STCW training demands on seafarers' shore-leave recovery. The research idea is grounded in competence-based training principles delivered by the International Maritime Organization (IMO) on fatigue guidance and welfare expectations reflected in the Maritime Labour Convention (MLC). It captures training exposure, delivery mode, training governance quality, early re-contracting pressure, psychological detachment during leave, perceived recovery, and safety- and retention-related outcomes. The proposed framework enables analysis of key interchanges between competence assurance, recovery protection and relevance of the non-STCW training, including the conditions under which digital and hybrid training models may mitigate or aggravate fatigue. By explicitly linking training delivery and governance practices, the study addresses a critical gap between regulatory intent and seafarer experience. This paper contributes to enhancing the policy evaluation framework in supporting maritime administrations, training providers, and shipping companies in developing training systems that maintain safety standards while safeguarding seafarer wellbeing.

Maritime Competences for the Future: Role of Internationalization in Transversal Skills Development

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Keywords: maritime education; transversal skills; internationalization; competence development

Maritime innovations mainly related with technological improvement and globalization have led to a fast development of maritime industry, meaning that the concept of maritime competencies needs to be reviewed entirely. This paper investigates the paramount of internationalization for the foment of horizontal competences in the formation of merchant navy. The increasing internationalization of the industry, traditional technical skills alone are no longer sufficient for the rural profession to meet further challenges. Soft skills – intercultural communication, flexibility, ability to solve problems and leadership - have become increasingly important for the maritime practitioner. The present paper examines how internationalizing processes in maritime education can be expected to facilitate the acquisition of these essential transversal competences.

The symbiotic between internationalization and transversal competences development is explored based on an analysis of the maritime courses and industry competences needs. The research design is underpinned with a qualitative educational framework analysis and multiple case studies of the leading maritime universities. The findings of the research reveal that internationally structured activities, such as student exchange, international cooperation and cross-cultural components/courses, do enhance the development of transversal skills in maritime education (students and professionals).

The findings suggest that opportunities to work in different international environments especially increase the development of suite of key transversal capabilities, in particular relating to cultural sensitivity, communication skills and adaptive decision making. In addition, the research indicates that universities with more concerted internationalization strategies are more likely to have higher graduate employability and do better on industry-side data on future-ready attributes – as demonstrated by the institutional survey and industry feedback. These results are significant for maritime education policy, curriculum creation, and industry collaboration. The paper ends with some recommendations for the integration of internationalization within maritime education programs to enhance the acquisition of transversal skills, and to prepare maritime practitioners to face the increased complexity of the future maritime industry.

Challenges and Possible Solutions for the Early Seafaring Career in Dynamic and Changing Environment

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Keywords: career start at sea; young seafarers, transformation processes in the maritime domain; human factor in the maritime domain

The rapidly changing maritime environment with new economic, technical, ecological and digital realities requires strong adaptiveness and flexibility. The changes affect the maritime education and training, specialized and standardized to adapt to the new realities and opening "wider field of opportunities" for young seafarers at the start of their career. Recent researches focus on conclusions that outline models of basic maritime education that combine fundamental technical knowledge with different set of socio-economic and digital skills applied in inter-connected aspects of the seafaring profession. In this context, some important questions tend to appear and influence the attitudes of the young seafarers about the seafaring career during their last two years of education, especially after concluding their cadets' internships.

The paper examines the attitudes of students from 3rd and 4th year of maritime specialties "Navigation" and "Ship engineering" towards the start of their seafaring career measuring levels of expectations versus real-life experience after onboard internship. The goal is to outline areas of challenges and possible solutions for the preparing academic institutions and the "users" of the young seafarers in order to provide smoother and adequate transition from education to career start in dynamic environment. The research puts a benefit at the level of initial motivation and following overview of the basic assumptions for continuous professional development. The methodology is based on a survey with open questions aiming to achieve more honest and objective results.

In the first part an overview of the basic MET (Maritime Education and Training) principles is presented based on new socio-economic and digital maritime environment realities: learning through mentoring, training using case studies and shared learning. Combining classical education with new approaches like human-centered training, self-education etc aims to broaden the view and the attitudes of the students and to correspond to employers' needs and requirements. The paper presents summary of the empirical data from students' experiences after the cadets' internships emphasizing organizational management aspects like human and resource management onboard. The results from the survey summarize the challenging areas that will affect the future motivation and career path. Conclusions show readiness to finish the education with partly declared intention for commencing career onboard as well as initial intentions towards the duration of the onboard career between five and ten years.

Additional feedback from the employers is analyzed in order to outline possible solutions towards the presented tendencies. The conclusions include approaches towards motivations and expectations implemented in the initial early training. Some suggestions reach to the inclusion of the employers role during cadets internships in order to match needs of the both sides that have empirical based effect in the professional decision-making of young seafarers.

Turnover Intention and Quiet Quitting among Seafarers: The Role of Demographic and Job-Related Characteristics

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Keywords: seafaring; turnover intention; quiet quitting

The global maritime industry faces ongoing challenges related to workforce retention and engagement, highlighting the importance of understanding factors that shape seafarers' organizational attitudes and behavior. This study examines how demographic factors (age, gender, nationality, educational attainment, marital/partner status, and having children) and job-related factors (tenure in seafaring and within the current company, vessel type, onboard position, and income level) are associated with two organizational outcomes: turnover intention (TI) and quiet quitting (QQ). TI refers to deliberate consideration of leaving their employer, while QQ reflects reduced work engagement, i.e., performing only the minimum required tasks.

The study draws on survey data from 508 active seafarers, primarily from Southeastern Europe, recruited via convenience sampling. The results showed that, among the examined characteristics, TI was significantly associated with age, total seafaring experience, and tenure with the current company, with younger and less experienced seafarers reporting higher levels. It was also related to educational attainment, income level, and onboard position, with higher TI observed among seafarers with higher education, lower income, and among senior deck personnel compared to senior engineering staff. Additionally, Croatian seafarers reported higher TI than Greek seafarers. With respect to QQ, significant associations were observed with age, total seafaring experience, and tenure with the current company, indicating higher levels among younger and less experienced seafarers. QQ was also significantly associated with income and having children, with higher-income seafarers and those with children reporting lower levels of QQ.

Although the results highlight the relevance of demographic and job-related characteristics for TI and QQ, given the non-representative sample and the relatively modest associations, the findings should be interpreted with caution. Nevertheless, they provide an empirical basis for future theory-driven research and offer practical insights for shipping companies aiming to implement targeted retention strategies, enhance onboard working conditions, and support long-term workforce stability.

Command in the Digital Age: Bridging the Leadership Gap to Retain the 'Generation Z' Officer

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Keywords: leadership; generation z; retention; culture; psychological safety

The maritime industry is undergoing a generational transition as Generation Z officers enter shipboard environments structured around established hierarchical command systems. Although digitalization has transformed vessel operations, leadership practices have evolved more gradually, creating a “Leadership Lag” between traditional authority models and the psychosocial expectations of younger officers. This misalignment is increasingly reflected in retention challenges, suggesting that financial incentives alone do not address underlying motivational drivers.

This study examines two dimensions of this leadership friction: the “Psychological Safety Gap,” defined as the discrepancy between expectations of open communication and perceived hierarchical rigidity, and the “Connectivity Paradox,” wherein increased onboard digital connectivity may unintentionally reduce crew cohesion.

A mixed-method design was employed. A quantitative survey of deck cadets and junior officers assessed the relationship between perceived leadership style and intent to quit. Semi-structured interviews with senior officers explored command challenges in managing younger crews. Statistical and thematic analyses were conducted to identify convergent patterns.

The paper proposes that command effectiveness in the digital age depends not only on rank and regulatory compliance but also on emotional intelligence and adaptive communication. It introduces a "Human-Centred Command Framework" that integrates traditional authority with modern mentorship competencies. The findings suggest that bridging this leadership gap is critical for retaining Generation Z officers while maintaining the operational discipline, safety standards, and command integrity required in an increasingly digital maritime environment.

Human-Centered Digitalization: An Actionable Framework for Digital Literacy for Transitioning to Future Shipping

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Keywords: Maritime Education and Training (MET); maritime digitalization; human-centered digital transformation; shipping; MASS

Digitalization is rapidly transforming the maritime operations to enhance safety, environmental performance, and regulatory compliance. However, dominant digital transformation strategies of shipping companies is largely based on the assumption that upskilling of the maritime workforce is supported by formal Maritime Education and Training (MET) systems and there is adequate financial capacity to implement that. However, this overlooks the reality that more than half of the oceangoing seafarers (1.03 million) are ratings - typically non-officer, that mainly rely on informal training onboard. This makes a major workforce segment that are overlooked in maritime digitalization strategies. This paper argues that such assumptions undermine workers' effective engagement with digital systems. This is critical as it has direct consequences for operational safety, environmental protection, and regulatory adherence specially as we are transitioning to MASS.

To have a better understanding of the readiness of maritime industry for progressing to smart and autonomous shipping we developed a research based on a critical review of maritime digitalization and MET literature. This study identified and conceptualized a digitalization–skills mismatch, whereby the speed, complexity and design of digital adoption exceed the absorptive capacity of informally trained maritime ratings. The analysis demonstrates that this mismatch represents a structural challenge rather than a transitional limitation, as existing MET models, training delivery mechanisms, and educational investment frameworks are not aligned with the realities of ratings as low-skilled workers in marine operations. Our study revealed that from the financial perspective this constrained operating margins limit the feasibility of conventional digital training investments. While from a human resource perspective, informal learning practices, limited digital literacy, and job insecurity shape workers' engagement with digital systems. These findings have direct implications for safety, compliance, and environmental protection of shipping industry.

The outcome of this research is a human-centered analytical framework for maritime digitalization that emphasizes task-based competence, embedded learning, and inclusive training design. This study, by reframing digitalization as a workforce-capability challenge rather than a purely technological issue. The proposed framework delivers actionable insights for MET institutions, policymakers, and maritime operators seeking to ensure effective, safe, and inclusive digital transformation in the global maritime industry. These insights hold broad global relevance and support workforce sustainability, safe operations, and the international shipping sector's capacity to meet evolving environmental and regulatory standards.

Designing Affective Learning Pathways in Maritime Education and Training

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Keywords: affective learning; appreciative inquiry; cultural intelligence; international exchange; pedagogy

As artificial intelligence continues to automate higher-order cognitive tasks, maritime education and training programs must increasingly emphasize distinctly human capacities such as empathy, intercultural sensitivity, and value-driven leadership. Building upon the previous mixed-methods study that demonstrated moderate-to-high affective internalization among U.S. maritime business students participating in a short-term experiential program in Japan, this follow-on study presents the design of a new affective learning model intentionally embedded within an international maritime program.

Drawing upon the pedagogical practices (such as structured reflection, emotional dissonance, and intercultural engagement), the short-term experiential program has been redesigned to understand a wide variance in psycho-social development and to elicit maximal affective learning. In particular, the program will intentionally incorporate the following new elements:

- Expanded intercultural exchanges with Japanese university students to reinforce perspective-taking, empathy, and characterizing behaviors;
- Appreciative inquiry-based practices (including reflection) that emphasize growth-minded inquiry, gratitude, and relational meaning-making; and
- Emotionally resonant field excursions, particularly at the Hiroshima Peace Memorial Park, designed to evoke values questioning and internalization.

This paper will outline the theoretical rationale, pedagogical structure, and expected affective outcomes supported by two decades of affective learning research. We argue that integrating appreciative inquiry and emotionally significant excursions provides a replicable pathway for maritime education and training institutions seeking to cultivate psycho-social competencies at scale. The redesign anticipates amplifying students' cultural intelligence (CQ) generally (but also their affective drive in particular) while fostering deeper identity reflection, value organization, and long-term behavioral internalization.

This extended model provides the maritime education and training community a proactive way to respond to industry needs by preparing future global maritime professionals who bring not only technical proficiency but also the emotional resilience and intercultural awareness essential for leadership in an increasingly complex world.

The Impact of Digitalization on the Maritime Sector: An Analysis of Career Opportunities and Challenges for Maritime Students

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Keywords: digital ocean; future employability; maritime students; maritime education and training

The rapid development of digital technologies is transforming the maritime sector into what is increasingly described as a “Digital Ocean”. Technologies such as artificial intelligence, big data analytics, digital twins and smart management systems are reshaping maritime operations, human resource management and educational requirements (Theotokas and Lagoudis 2024; Albà 2025). This transformation is closely aligned with the IAMUC 2026 theme of human-centred digital oceans, which emphasizes the preparation of safe, competent and globally oriented maritime professionals. This study examines how digitalization influences the future employability of maritime students. Drawing on a systematic literature review of recent research on maritime education and digital human resource management (Mehrotra et al. 2025; Pratiwi 2024; Scanlan et al. 2022), the paper identifies emerging employment opportunities and barriers that maritime students may encounter. The findings indicate that digital transformation raises competency standards, requiring advanced digital literacy, interdisciplinary knowledge and adaptive soft skills from future professionals (Albà 2025; Scanlan et al. 2022). Therefore, Maritime Education and Training (MET) institutions must adjust and modernize maritime education by integrating digital technologies and competencies into their training frameworks, alongside adopting human-centred educational approaches (Mehrotra et al. 2025).

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Mental Fortitude at Sea: Supporting Seafarers in Crisis Zones

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Keywords: seafarers; mental health; working environment

Seafarers working in conflict areas need to be highly resilient in terms of psychological strength due to the risks of physical harm and geopolitical instabilities. The key to safe and secure navigation is to prioritize mental health as part of resilient crew management. The objective of the work is to create awareness about the need of the training programs that cover conflict, stress, high-pressure communication, and mental health issues to enable seafarers to deal with them and avoid escalation. The research work constitutes empirical qualitative information from the seafarers who have been worked in these conflict prone and geopolitical unstable areas. The research speaks about knowledge of legal rights and support services during stressful times which is important to maintain resilience. Seafarers should be made aware of their rights and the services available to reduce stress and maintain focus. The research work also deals with various general support for developing inclusive policies that safeguard rights and welfare of the seafarers. It also includes issues like various sanctions that may impact routes and navigation, thereby increasing stress associated with employment and working conditions. The research work concludes with strong points directing immediate requirements of organizations to explore various training methods and find ways to ensure the mental well-being of seafarers. International maritime law is an important consideration in safeguarding seafarers during times of crisis, leading to confident and secure navigation.

Safety-Critical Challenges of Ammonia as a Marine Fuel: A Human-Centered Risk Perspective

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Keywords: shipboard safety; human-centered; crew competence; alternative marine fuels; maritime safety management

The maritime sector is actively exploring alternative fuels to meet international decarbonisation targets, with ammonia emerging as a promising candidate due to its carbon-free combustion and established global supply chain. While significant attention has been given to the technical feasibility and environmental benefits of ammonia-based propulsion systems, comparatively less emphasis has been placed on the safety implications associated with its operation at sea. Ammonia's high toxicity, corrosive nature and distinct handling requirements introduce safety challenges that differ substantially from those of conventional marine fuels and other alternative options such as LNG and methanol. Recent studies have demonstrated that ammonia leak dispersion and exposure in enclosed shipboard spaces can pose serious risks to personnel, particularly in machinery spaces (Yadav and Jeong 2022).

This paper examines the adoption of ammonia as a marine fuel through a human-centred safety lens, focusing on the interaction between complex fuel systems and shipboard personnel. Key safety-critical scenarios are identified, including fuel leakage, exposure risks during bunkering and operation, emergency response requirements and the potential consequences of human error in high-risk environments. The analysis highlights how the introduction of ammonia-based systems alters established operational practices and places new demands on crew competence, situational awareness and decision-making under emergency conditions.

By comparing ammonia-related risks with those associated with existing marine fuels, the study emphasises the need for safety frameworks that extend beyond technological safeguards alone. Particular attention is given to gaps in current training standards, onboard procedures and emergency preparedness that may hinder the safe integration of ammonia-fuelled vessels into commercial operations. A systematic review of ammonia safety literature highlights regulatory and risk-assessment gaps that must be addressed to protect personnel in ammonia-fueled operations (Pocitarenco et al. 2025). The paper argues that successful adoption of ammonia in shipping depends not only on engineering solutions but also on the development of robust human-centred safety strategies, supported by targeted education and training of marine professionals. These findings aim to inform educators, regulators and industry stakeholders seeking to balance environmental performance with operational safety in the transition to low-carbon maritime fuels.

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Key Competencies for Sustainable Maritime Entrepreneurship

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Keywords: key competencies; sustainable maritime entrepreneurship; regulatory compliance; digital competencies; sustainable management

The accelerated introduction of international and European regulatory frameworks for reducing greenhouse gas emissions from shipping, the European Union's initiatives to achieve climate neutrality by 2050, as well as the commitments undertaken by port communities to implement the United Nations Sustainable Development Goals, impose new requirements on the functioning and behavior of entities in the maritime sector. In this context, sustainable maritime entrepreneurship is regarded as a driver of innovative solutions that balance economic goals with social responsibility and environmental protection. Based on an analysis of survey data collected from sector managers, the study identifies an urgent need to implement sustainable innovations through a workforce equipped with key competencies in decarbonization, digitalization, and the efficient management of maritime, port, and logistics processes. The purpose of the publication is to identify and systematize an integrated set of environmental, regulatory, digital and managerial skills and competencies that maritime universities should develop in future specialists of maritime transport with a view to the effective application of innovative technologies, means, and methods for achieving the principles of sustainable development in a real operational environment. To achieve the objective, two main methods were applied. The first involves an analysis of key international and European strategic documents with the aim of identifying the knowledge, skills and competencies necessary to overcome operational and environmental risks and to implement sustainable practices. The second method is survey-based and involves the application of Likert scales among managers in the sector, in order to establish the degree of training and actual competence in relation to the new requirements. The analysis of the results indicates that the key competencies with the greatest significance for the sustainable development of the maritime business can be summarized in four main categories: Environmental and energy competencies; Regulatory competencies; Digital and analytical competencies; Managerial and transversal competencies. The publication identifies and systematizes the key competencies essential for the advancement of sustainable maritime entrepreneurship and for the effective training of future maritime professionals. The development of these competencies within maritime universities is of critical importance for ensuring a highly qualified workforce capable of applying innovative technologies and methods, maintaining regulatory compliance, and implementing sustainable solutions in a real operational environment. Furthermore, the study recommends the use of integrated training and assessment approaches—such as simulations, case studies, and expert interviews—to enhance the practical relevance and applicability of maritime education.

Has *She* Been Promoted, or at Least Neutralized?

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Keywords: Maritime Labour Convention; gender-bias; gender-neutral language; corpus-based analysis

In an effort to enhance both the participation and the visibility of women in maritime professions, the International Maritime Organization established its Women in Maritime Programme in 1988. Since then, it has undertaken revisions of several international legal instruments to address gender-related concerns more explicitly. The present study focuses on the convention most directly concerned with the rights and working conditions of seafarers, namely the Maritime Labour Convention from 2006. The Convention consolidates and revises 37 earlier maritime labour conventions (MLC 2006: 6), thereby providing a comprehensive framework for seafarers' rights.

To examine potential shifts in gendered terminology, we conducted a comparative linguistic analysis of the MLC, 2006 and the 37 conventions it supersedes. Two parallel corpora were compiled for this purpose, enabling systematic quantitative and qualitative analysis – MLC Corpus (41,988 tokens or 3707 word types) and Previous Conventions Corpus (87,951 tokens or 3392 word types. Text conversion, corpus preparation, and lexical profiling were carried out using Laurence Anthony's suite of corpus analysis tools, including AntConc (2024) and AntWordProfiler (2024).

The analysis began with an examination of the frequency of selected core lexical items, including pronouns (Table 1).

Table 1. Frequency-based comparison between the two corpora.

Word	MLC 2006	Previous conventions
seafarer	184	55
seaman/seamen	0	141
he/him/his	4	228
she/her	4	14
man /men	2	4
woman / women	0	0

The findings indicate a discernible shift toward gender-neutral forms of reference in addressing maritime personnel, most notably in the preference for seafarer over the gender-marked seaman. However, a more detailed terminological analysis reveals that gendered lexical patterns have not been entirely eliminated. For example, the term manning remains persistent even in contemporary instruments, appearing more than twenty times in the Maritime Labour Convention, 2006, whereas alternative gender-neutral forms such as crewing occur only twice, and staffing does not appear at all, regardless numerous research initiatives and recommendations (e.g., Bezhanović et al. 2024; Kitada 2025; Dževerdanović-Pejović 2020; Đurović et al. 2026).

Previous research (e.g. Liu et al. 2023; Boström 2025; Đurović et al. 2026) has identified numerous additional examples of persistent gender bias in maritime discourse and lexicography, particularly in relation to man-based onboard titles (e.g., helmsman, pumpman, able-bodied seaman). Nevertheless, maritime legislation — international conventions in particular, appears to represent a comparatively progressive domain within the broader maritime industry. Such developments not only contribute to challenging gender stereotypes within the maritime sector but may also support broader societal efforts toward linguistic and structural equality.

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Beyond Standard Operating Procedures: A Framework for Simulation-Based Learning in Marine Engineering

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Keywords: maritime education and training; simulation-based learning; expansive learning; experiential learning

Simulation-Based Learning (SBL) has long been an integral component of Maritime Education and Training (MET). The pedagogical traditions and didactic approaches within MET SBL have been largely developed with a navigational focus, alongside models adapted from external fields such as aviation and healthcare. Consequently, Marine Engineering SBL lacks a distinct, domain-specific pedagogical foundation. Instead, it relies heavily on these inherited practices, driven largely by high technical fidelity and realistic system complexity. These approaches often fail to address the specific socio-technical complexity of modern engine room operations, necessitating a re-evaluation of how engineering competence and knowledge are constructed in simulated environments.

This study addresses the research question: What are the essential aspects of a foundational framework for higher education engineering SBL? The objective was to develop a conceptual framework that elevates SBL design from mere technical proficiency, standard operational procedures, and resource management to a holistic socio-technical activity system.

The methodology employed was theory synthesis. This approach was selected to achieve conceptual integration by linking three previously distinct theoretical lenses: Experiential Learning Theory, Reflective Practice and Expansive Learning Theory. By summarizing and integrating these theories, the study offers a novel perspective on engineering pedagogy. A rapid literature review was conducted as a supporting step to map the fragmented landscape of current MET SBL research, informing that no domain-specific SBL framework currently exists for marine engineering. The synthesis addresses this gap by transforming previous findings into a cohesive model.

The resulting framework positions the simulator not merely as a replica of reality, but as a mediating tool within an activity system in which the subject reflects the required knowledge. This framework proposes that while the experiential learning cycle is effective for individual skill training and reducing cognitive load in well-structured tasks, both reflective practice and expansive learning are required to master ill-structured, collaborative problems in complex socio-technical environments, such as a control room on a ship or in a power plant. The framework maps the transition from theoretical knowledge and standard operating procedures to adaptive problem-solving, providing design principles for complex ill-structured engineering scenarios.

This study contributes a novel theoretical perspective to the expanding field of high-fidelity engineering simulations. By integrating individual learning cycles with expanding learning theory, the proposed framework offers a robust basis for designing SBL that matches the complexity of real-world operations. Future research should focus on empirically testing and iteratively refining this framework within active marine engineering curricula.

Unmasking the Hidden Waves of Distress: A Latent Profile Analysis of Seafarers' Anxiety and Depression

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Keywords: seafarer; mental health; Latent Profile Analysis; anxiety; depression; life satisfaction

The demanding nature of the seafaring profession places seafarers at a high risk for mental health issues. Among these, anxiety and depression are particularly prevalent and pernicious (Sánchez-González et al. 2024). When co-occurring, these conditions can create a synergistic negative effect, severely impairing cognitive functions critical for safe navigation and on-board operations, while deepening feelings of isolation and hopelessness inherent in life at sea. This study adopts a person-centered approach, Latent Profile Analysis (LPA) (Spurk et al. 2020), to identify distinct profiles of co-occurring anxiety and depression and to examine their differential impacts on well-being.

A survey was conducted with 991 active Chinese seafarers. Latent Profile Analysis (LPA) was performed on their anxiety and depression scores to identify distinct subgroups. The optimal five-profile model was selected based on a comprehensive evaluation of statistical fit indices (e.g., AIC, BIC), classification accuracy (Entropy), and likelihood ratio tests (LMR, BLRT), in conjunction with theoretical interpretability. Subsequently, the BCH method was used to compare the mean differences in life satisfaction and work-family conflict across these profiles, correcting for classification errors. For all four scales used, higher scores indicate a higher degree of the respective construct.

The LPA results successfully identified five distinct mental health profiles: 1) "Healthy" (5.6%), characterized by low levels of both anxiety and depression; 2) "Predominantly Depressive" (24.3%), with high depression but low anxiety; 3) "Moderate Distress" (42.1%), showing moderate levels of both symptoms; 4) "High Depression-Moderate Anxiety" (22.2%); and 5) "Severe Comorbidity" (5.8%), a high-risk group with the most severe symptoms of both conditions.

Subsequent analysis revealed a clear gradient effect. As the severity of psychological distress increased across the profiles, life satisfaction significantly decreased, while work-family conflict significantly increased. For instance, all other profiles showed significantly lower life satisfaction compared to the "Healthy" group. However, some nuanced non-significant differences also emerged: the "Healthy" and "Predominantly Depressive" groups did not differ in their work-family conflict, and similarly, the "Predominantly Depressive" and "Severe Comorbidity" groups reported no significant difference in life satisfaction. Nevertheless, the "Severe Comorbidity" group ultimately reported the lowest overall life satisfaction and the highest work-family conflict, unequivocally identifying them as a highly vulnerable population. These findings demonstrate that seafarers' mental health challenges are not uniform but fall into distinct patterns. This research provides a crucial empirical foundation for developing differentiated, profile-specific support strategies for the maritime industry.

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Human-Centred Safety Practices in the Handling of Dangerous Goods in Maritime-Port Systems

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Keywords: dangerous goods; IMDG Code; maritime safety; human factor; safety culture

The transport and handling of dangerous goods (HAZMAT) in maritime and port environments represent a critical challenge for shipping safety and environmental protection. Although comprehensive international regulations exist—namely the IMDG Code and the SOLAS and MARPOL Conventions (IMO 2024)—accidents and operational deviations continue to occur, often associated with human and organisational factors (Khan et al. 2022). This study investigates the level of safety awareness and the practical application of safety procedures related to dangerous goods handling both on board merchant vessels and within maritime-port clusters.

A mixed-methods approach was adopted, combining documentary analysis, structured questionnaires administered to maritime professionals, and field observations in port terminals. The research focused on operational contexts in selected Portuguese ports and on board merchant vessels, aiming to identify behavioural patterns, training gaps and organisational constraints that influence safety performance.

The results indicate a positive evolution in safety awareness; however, they also reveal limited routine consultation of IMDG documentation, inconsistent monitoring of dangerous cargo during voyages and insufficient company-provided training programmes. Such operational gaps may contribute to increased risk, including misdeclaration and inadequate handling procedures reported in containerised transport (Maternová and Materna 2022). The findings highlight the central role of the human factor in risk management and demonstrate that compliance with technical regulations alone is insufficient without a strong safety culture supported by continuous education and organisational commitment (Reason 1997). Respondents expressed a clear interest in further training on dangerous goods regulations, suggesting a mismatch between workforce needs and organisational investment in professional development.

This research contributes to the discussion on human-centred maritime safety by emphasising the importance of education, procedural standardisation and intermodal coordination in the management of dangerous goods. It also underlines the potential of digital monitoring and cargo-tracking tools as enablers of safer practices, provided that maritime professionals are adequately trained to integrate these technologies into daily operations. The study supports the development of educational and managerial strategies aimed at preparing safe and environmentally responsible maritime professionals for increasingly complex and digitalised maritime-port environments.

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The Silent Side of Maritime Stress: Why Lonely Seafarers Withdraw

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Keywords: seafarers; emotional strain; loneliness; coping strategies; social withdrawal

Stress in maritime settings is typically discussed through operational demands such as workload, fatigue, and organizational working conditions. However, the emotional dimension of seafarers' psychological experiences remains comparatively underexplored. The aim of this study was to examine the association between emotional stressors and patterns of coping among seafarers.

The study was conducted on a sample of 135 seafarers across different ranks and vessel types. The analysis focused on indicators of emotional strain, including loneliness, social isolation, separation from family, and concern for family members, as well as stress-coping strategies.

Findings indicate that a substantial proportion of respondents reported emotional strain; more than one third of seafarers (≈35–40%) identified loneliness and/or separation from family as a relevant source of burden while working on board. These emotional stressors showed a systematic association with maladaptive and withdrawal-oriented coping strategies. Rather than displaying pronounced externalized reactions, emotionally burdened seafarers more often resorted to psychological distancing, social withdrawal, and withdrawal-oriented coping patterns.

Overall, the results suggest a "silent" dimension of maritime stress that may remain unrecognized within standard psychosocial risk assessment frameworks. Such coping patterns may have longer-term implications for seafarers' wellbeing, interpersonal relationships, and occupational safety. The findings highlight the importance of integrating emotional and interpersonal components into seafarer support, including organizational, communication, and mentoring interventions.

Development and Validation of the Crew Diversity Maturity Index (CDMI): A Case-Based Self-Assessment Framework for Maritime Diversity Education

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Keywords: crew diversity; diversity maturity index; case-based learning; maritime education; intercultural competence

The increasing diversity of crew composition in the global maritime industry presents both opportunities and challenges for shipboard operations (Cox and Blake 1991). Multinational crews, comprising seafarers from different cultural, linguistic, and religious backgrounds, must work together in confined spaces for extended periods, making effective diversity management essential for operational safety and crew well-being. However, existing maritime education and training (MET) programs lack systematic frameworks for developing seafarers' diversity competencies (Theotokas and Progoulaki 2007; Horck 2010; Progoulaki and Theotokas 2016). This study addresses this gap by developing and validating the Crew Diversity Maturity Index (CDMI), a comprehensive self-assessment tool designed to measure and enhance maritime professionals' diversity management capabilities.

The CDMI framework adapts Thomas's (1991, 1996, 2010) Personal Diversity Maturity Index (PDMI) to the maritime context, establishing a seven-stage developmental model: Denial → Awareness → Understanding → Acceptance → Internalization → Behavior → Integration. The instrument comprises 15 conflict categories derived from empirical analysis of shipboard incidents, including hierarchy conflicts, sexual harassment, cultural discrimination, communication barriers, religious practices, gender issues, and generational gaps (Choi 2024; Choi 2025). Each category features scenario-based learning modules with Extended Reality (XR) web drama content recreating authentic shipboard environments, enabling learners to engage with realistic conflicts through QR-linked videos, respond to assessment items, calculate maturity scores, and engage in reflection.

The educational model integrates case-based learning with self-assessment, allowing learners to view realistic conflict scenarios via QR-linked videos, respond to Likert-scale items, calculate their maturity scores, and engage in guided reflection. A validation study involving 30 maritime professionals (53% from maritime education institutions, 86% with over 5 years of experience) yielded highly positive results: 100% agreed that XR-enhanced scenarios improved learning immersion, 90% confirmed the scenarios accurately reflected shipboard realities, and 97% endorsed the comprehensiveness of the 15 conflict categories. The CDMI workbook structure received 100% positive evaluation for its systematic design. Notably, 90% of respondents expressed intention to adopt the materials in their institutional training programs, while identifying insufficient crew motivation (40%) and lack of organizational support (37%) as the primary barriers to implementation.

This study contributes to maritime education by providing a theoretically grounded, empirically validated tool for diversity competency development. The CDMI framework aligns with the conference theme of educating human-centred maritime professionals by addressing the social dimensions of shipboard safety. Future development will include English-language versions, additional scenario modules, and instructor guides to facilitate broader implementation across IAMU member institutions.

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Enhancing Maritime English Teachers' Digital Competence for Effective Online Teaching

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Keywords: digital technologies; e-learning; maritime professionals

The article examines the formation and development of digital competence among Maritime English teachers within the framework of modern educational challenges. The digital competence of teachers has become a key factor in ensuring the quality and continuity of education, particularly in specialised fields such as maritime education (Bykov & Ovcharuk 2017). The study conceptualises digital competence as a complex, dynamic and integrative professional characteristic encompassing technological, pedagogical, ethical and reflective dimensions (Abduh et al. 2022, Carretero Gomez et al. 2017). The research employs a mixed-methods approach combining theoretical analysis of scholarly literature and regulatory documents with empirical methods, including questionnaires, semi-structured interviews, pedagogical observation, and analysis of digital instructional materials (European Comission 2019). Elements of a formative experiment and basic statistical analysis were used to assess changes in teachers' digital skills following targeted professional development initiatives. The findings demonstrate that effective use of digital tools, learning management systems, virtual communication platforms and interactive resources enhances learner engagement, supports flexible instructional formats, and strengthens teachers' professional effectiveness (Bykov et al. 2020, Diahyleva et al. 2023). At the same time, the study identifies persistent challenges, such as insufficient technical infrastructure, uneven levels of digital readiness, and limited methodological support. The article concludes that general dynamics of increasing the level of digital the competence of teachers is positive, but not intense enough, which is associated with certain limitations: a quick transition to distance learning and insufficient preparedness of the system of postgraduate education. Teachers are gradually mastering new digital technologies for the implementation of distance education studies in Maritime institutions.

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A Qualitative Analysis of Affective Learning Outcomes in Marine Transportation Curriculum

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Keywords: affective domain; affective learning outcome; maritime education and training

Despite the growing recognition of the significance of the affective domain – the realm of feelings, emotions, attitudes, interests, degrees of acceptance or rejection and values, and the increasing advancements in Maritime Education and Training (MET), MET institutions continue to prioritize cognitive and psychomotor domains, leaving a critical gap in developing affective dispositions as part of the overall competency of seafarers. This study investigated the extent to which affective learning outcomes are included in the Bachelor of Science in Marine Transportation (BSMT) curriculum in a MET institution in the Philippines. The research employed a qualitative dual-stage design. First, a document analysis was conducted on the 36 existing deck course manuals to determine the presence of explicit affective learning outcomes based on the taxonomy developed by Krathwohl et al. (1964). Second, semi-structured interviews were held with two (2) deck curriculum developers to explore the underlying barriers to inclusion and to identify the potential inclusion points for affective pedagogy with the existing framework. The document analysis revealed a significant void: zero explicit learning outcomes were identified in all the course manuals. Interview data highlighted that the primary barrier is the “alignment trap”. Developers noted that the national minimum standards set by the Administration were based almost exclusively on STCW-mandated technical competencies, leaving little regulatory “room” for affective inclusion. However, developers did identify specific maritime courses where affective learning outcomes could be embedded. The study concludes that the absence of affective learning outcomes is not a result of professional indifference, but a systemic reliance on rigid regulatory frameworks that overlook the affective domain. It is recommended that the Maritime Industry Authority (MARINA), the one that oversees MET in the Philippines, revise minimum standards to mandate affective competencies; and broadly, the same should be included in the next revision of the STCW. Furthermore, curriculum developers should utilize the identified courses to pilot integrated affective learning outcomes. Future researchers may also investigate the areas of delivery and assessment to determine the explicit and implicit integration of the affective domain.

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From Abandonment to Key Workers: The Impact of the 2014-2025 MLC Amendments on Seafarers' Labour Rights

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Keywords: MLC 2006; Article XV Code amendments; abandonment; on-board complaints; key workers

The Maritime Labour Convention, 2006 (the MLC) occupies a distinctive place in the international protection of labour at sea, as it consolidates minimum standards for seafarers' working and living conditions within a single document and provides a supervision and enforcement framework tailored to maritime administrations and operational practice. While the Articles and Regulations may be amended only at an ILO international conference pursuant to Article 19 of the ILO Constitution and Article XIV of the Convention, the Code may, under Article XV of the MLC, be amended through a simplified procedure without further ratification. This simplified Code amendment procedure enables the MLC to respond relatively swiftly to recurring practical issues that directly affect seafarers' labour-rights protection.

The paper applies a systematic legal (doctrinal) analysis of the MLC Code amendment packages adopted in 2014, 2016, 2018, 2022 and 2025. he packages are grouped by labour-rights risks (remedies/financial security; continuity of rights in exceptional circumstances; procedural safeguards) to assess their cumulative effect on practical protection. Since its entry into force, the MLC has been amended five times. The 2014 amendments were pivotal, introducing mandatory financial security for abandoned seafarers and for certain contractual claims related to death or long-term disability, thereby strengthening legal certainty as regards the practical realization of core entitlements in employment relationships at sea.

The 2016 and 2018 amendments broaden the protection of seafarers' labour rights in international navigation. Harassment and bullying on board are linked to the occupational safety and health framework, confirming that such protection is not confined to working time, wages, or the seafarer employment agreement, but also extends to the working environment in which those rights are exercised. The 2018 amendments further safeguard continuity of fundamental labour rights, such as the validity of the employment agreement, wages and repatriation, in situations of captivity caused by piracy or armed robbery, i.e., where the seafarer is objectively unable to influence the course of the employment relationship.

The 2025 amendments further strengthen the practical protection of seafarers' labour rights. Repatriation is reinforced as a non-discriminatory right, with clarification of the minimum scope of costs, including medical treatment until the seafarer is fit to travel. In addition, on-board complaints procedures are strengthened by procedural safeguards, including confidentiality, access to assistance, and protection against victimization. Violence and harassment, particularly sexual harassment, are also expressly incorporated within the occupational safety and health framework. Particular emphasis is placed on the obligation of Member States to designate their seafarers as key workers to facilitate their movement in connection with employment, including crew changes, shore leave, and access to shore-based healthcare.

Taken together, the amendments adopted between 2014 and 2025 demonstrate that the MLC is evolving to strengthen the protective mechanisms most often needed by seafarers in practice: security in cases of abandonment, effective repatriation, and procedural guarantees for making complaints without fear of adverse consequences for the complainant. For this reason, the paper emphasizes Article XV as the mechanism for targeted Code updates where practice reveals that labour-rights protection is inadequate.

Addressing Cultural Discount in Maritime English Communication: An AI-Enhanced Pedagogical Framework

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Keywords: maritime English; cultural discount; cross-cultural attitudinal strategies; AI-enhanced language training

Against the backdrop of the global shipping industry's transition towards greener, smarter, and safer operations, the International Maritime Organization (IMO) and the UN Sustainable Development Goal have set higher benchmarks for maritime talent development. However, a critical gap persists in their linguistic readiness for high-stakes cross-cultural communication, particularly in scenarios involving safety protocols, environmental technologies, and multilateral negotiations. This cultural discount phenomenon frequently leads to informational distortion and failure to achieve shared understanding. The study investigates the phenomenon of cultural discount—defined as systemic communicative inefficacy arising from socio-cognitive differences—within the oral practices of Chinese maritime EFL learners. Grounded in the IMO' s STCW Convention, which underscores cross-cultural competence, I examine how cultural-cognitive gaps manifest as expressive inaccuracies and resonance deficits in professional contexts.

This empirical research analyzes authentic, multi-modal discourse data—including group discussions, simulated negotiations, and thematic presentations—collected from the "Ocean Cup" Youth Competency Competition at Dalian Maritime University. The discourse revolves around pressing maritime issues: safety incident reporting, ship energy efficiency management, marine pollution prevention, and the interpretation of international maritime conventions. Following the International Maritime English Conference as key reference, the study conducts a fine-grained, four-dimensional analysis: lexical sophistication, syntactic richness, semantic clarity, cross-cultural attitudinal strategies. Findings reveal a distinctive high lexical complexity, low syntactic adaptability profile among Chinese maritime EFL learners. While they demonstrate the ability to employ a wide range of technical vocabulary, they exhibit significant weaknesses in organizing complex syntactic structures and constructing discourse that aligns with internationally recognized maritime textual norms. Moreover, pronounced semantic ambiguity and contextual disconnection were observed. These issues are particularly acute during cross-cultural value negotiations—such as prioritization of navigational safety—where learners frequently resort to strategies like literal translation from Chinese thinking patterns or cultural avoidance, thereby severely compromising communicative efficacy.

To address these challenges, this study proposes a tripartite, integrated "Language-Scenario-Culture" framework for competency enhancement, accompanied by actionable pedagogical interventions: (1) Developing a dynamic semantic-context adaptation system: Leveraging natural language processing technologies alongside maritime databases (e.g., GISIS, IMO regulatory texts), an AI-enhanced situational simulation platform will be developed. This system generates immersive maritime communication scenarios—such as presentations on low-carbon shipping initiatives—providing real-time feedback on linguistic complexity, discourse logic, and cross-cultural appropriateness. (2) Designing a cultural transposition training module: Centered on the international articulation of China's shipping story, this module involves narrative workshops focused on cultural transposition. Training encompasses multi-perspective interpretation of maritime safety culture, cross-contextual reframing of green shipping concepts, and strategic narrative adaptation for presenting Chinese proposals in global maritime governance.

The effectiveness of this proposed framework and interventions will be validated through empirical data and controlled pedagogical experiments. Furthermore, the study will introduce a Maritime English Competency Development Index to serve as an assessment tool for curriculum design in maritime institutions and cross-cultural training in corporate settings.

Rank and Experience as Determinants of Safe Passing Distance in Simulator-Based Environmental

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Keywords: COLREG; safe distance; MET; human factors; ship's bridge simulator

Safe passing distance remains a fundamental yet operationally subjective element of collision avoidance (Huang, Y. et al. 2020). While maritime education provides theoretical foundations based on COLREG, the practical interpretation of safe distance is shaped by professional experience, hierarchical structure on board, and individual risk perception (Kolakowski et al. 2025). Understanding how rank and sea service influence this perception is essential to the development of human-centred, competency-based maritime training models.

This study investigates how rank (Cadet, 3rd Officer, 2nd Officer, Chief Officer, Master) and professional experience (total sea service and service in rank) affect the perception and execution of safe passing distance in a full mission bridge simulator environment. The research integrates participants across the maritime hierarchy, enabling direct comparison between students, junior officers, and senior officers within standardized navigational scenarios.

Participants perform crossing (Rule 15) and head-on (Rule 14) encounters under controlled environmental conditions. The study analyses the minimum passing distance maintained and maneuver initiation timing. The primary research question examines how rank and accumulated experience influence both perceived and actual safe distance in a simulated operational context.

Preliminary assumptions suggest that cadets and junior officers may adopt more conservative safety margins, while senior officers may maintain smaller passing distances, reflecting confidence derived from experience and adaptive risk assessment. At the same time, hierarchical culture may contribute to the transmission and normalization of distance-related practices across ranks.

By combining maritime education and professional practice within a controlled simulator framework, this study contributes to the IAMU discourse on human-centred maritime training. The findings are expected to support the development of harmonized training standards that better reflect real-world hierarchical decision-making dynamics and promote consistent safety behaviour among current and future maritime professionals.

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Introducing a Collaborative Research Project for Maritime English Teachers

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Keywords: maritime English; maritime communication; classroom-based research methods

Engaging in classroom-based research provides maritime English teachers with a means to better understand student learning, evaluate pedagogical approaches systematically, and contribute to their professional community. A strong grasp of research methods is essential to plan and execute meaningful studies, but many teachers have limited training in this critical area. The goal of this presentation is to describe a unique approach to professional development that fosters skills and knowledge in classroom-based research methods and to introduce an implementation of this approach for maritime English teachers working in international settings.

In three separate year-long professional development projects, more than 100 language teachers across Japan received instruction on fundamentals of quantitative research methods, gained practical experience through execution of small-scale classroom studies, collaborated with other participants via online interaction, and examined learning in their own classrooms. In each project, teacher participants independently and concurrently replicated the same small-scale study in their classrooms, analyzed the data they collected, and published findings in in-house journals. Throughout the process, they shared experiences, gave advice, and received guidance through live video meetings and asynchronous online interaction. Program evaluations demonstrated strong positive experiences for the participating teachers, meaningful learning exchanges in the online forums, and tangible results in the form of academic presentations and publications.

With the aim of implementing a new iteration of this project within the community of international maritime English teachers, a procedures guide has been developed for a small-scale classroom study that explores the impact of the use of online learning tools (Digimar, English Central) to support instruction on maritime communication. The presenters will introduce this guide and describe an example of its use in a small pilot study with a maritime English course at a university in Japan. Interested teachers will be invited to join the upcoming project that is expected to launch in the fall of 2027. Project participants will receive guidance on relevant research methods, adapt the study for their own classrooms, and collaborate with other teachers throughout the planning and execution of their study. Project leaders will combine results across the studies, but teachers will be encouraged to publish and present on their own individual findings. The project aims to provide a professional development opportunity for maritime English teachers, explore the impact of using online tools to support training in maritime communication across varied settings, and foster deeper professional connections among local and international peers.

Artificial Intelligence and the Maritime Workforce: Potential Loss of Competence and Deskilling as Consequences

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Keywords: artificial intelligence; maritime workforce; deskilling; maritime education and training

Artificial intelligence (AI) gains swift progression across various domains and has lots of advantages, such as increased efficiency, new business models or putting forward the fourth industrial revolution, among other things. Maritime-related examples refer to the automation of routine tasks in navigation or cargo handling, enhancing safety, remote operations or overcoming the maritime skills shortage (see, for example, Emad et al. 2025; Rudzińska et al. 2024). At the same time, with the invention of AI also risks and disadvantages go along, such as concerns regarding ethics, data privacy, (cyber-)security, regulatory uncertainty or hurdles, job-related fears or job losses, among other things (see, for example, Bareis et al. 2026; Sheikh et al. 2023, p. 66 f.).

Since the rise of AI in general and in particular with the release of ChatGPT in autumn 2022 (OpenAI 2022), the primary question in terms of (lifelong) learning has been which new competencies are being needed and developed in order to be able to use such systems in a sovereign and prudent way (see, for example, European Commission 2025; OECD 2025, 2026; Palenski et al. 2024). The possibility of competencies being lost as a consequence of technological change (deskilling; Braverman 1974), and to what extent, is a phenomenon that receives less attention. In the maritime context, it plays (almost) no role at all (searches for titles, abstracts and keywords in the databases of Web of Science, Scopus and Google Scholar were performed). However, this paper aims to change the aforementioned situation.

Based on the definition of AI, the discussion will analyse in how far this technology can affect the loss, decline or erosion of skills, knowledge, judgment, competencies, experience and routine on an individual level (desktop research). However, the phenomenon is not new and has already been described in the context of industrial revolutions (Braverman 1974). The Cambridge Dictionary (n.d.) defines the verb ‘to deskill’ in this context as “to reduce the amount of skill that someone needs to do a particular job”.

The next step will be the analysis of the impact of AI on the maritime sector with emphasis on the workforce, working routines of nautical officers and further effects going along therewith. The results are intended to raise awareness of the relevance of the topic. Moreover, the results constitute a starting point for adapting training concepts of maritime education and training (MET) which are not limited to upskill and reskill people to ensure future-oriented MET (see above) but also consider the risk of deskilling (skills getting lost) as a consequence of a widespread use of AI in the maritime domain.

In the long term, it seems that these developments might result in safety risks. Examples in the maritime sector are technical failures of navigational equipment working properly under ‘normal’ conditions, over-reliance on automated systems or deliberate manipulation (jamming or spoofing), among other things. Different root causes can result in dangerous situations, which can be exacerbated by human error or miscommunication (Sánchez-Beaskoetxea et al. 2021; Dominguez-Péry et al. 2021). Therefore, the discussion is accompanied by the concept of situation awareness for the mitigation of potential risks (Endsley 1988).

In summary, the main idea is to shed light on this relevant and under-represented topic and start with an overview work. The methodological approach is to give an overview by analysing relevant prior works, theories and concepts and transferring these to the maritime context with the focus on MET (IAMU 2019) and lifelong learning (Ahmad Fuad et al. 2024; Bauk & Ilčev 2021). Therewith, the article addresses the social topics theme category of this year’s IAMUC; preference is oral presentation and the submission of a full paper.

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The Role of Soft Skills and English Language Proficiency in Maritime Logistics: A Comprehensive Analysis and Strategic Perspectives for Georgia

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Keywords: soft skills; Middle Corridor & Logistics; MET; human factor

The article deals with the challenges of maritime logistics education based on the demands of the contemporary labour market that operates in a complex, dynamic and international environment where professionals are required to make rapid decisions, coordinate multiple processes, and interact with diverse stakeholders. Compared to the background of globalisation, digitalisation, and growing geopolitical challenges, the maritime sector is transforming from “hard skills” to a “competence-based” model, where the human factor is the main guarantor of safety and efficiency. Within the framework of the study, special attention is paid to Georgia as a strategic hub connecting Europe and Asia and its role within the “Middle Corridor”. The paper discusses the need to integrate soft skills and English as international standards for maritime communication within the maritime education and training (MET) process. The implementation of "green technologies" in modern maritime logistics is directly related to soft skills and language competence.

The work explores effective teaching methodologies for students’ development that encompass fostering soft skills and English language proficiency as main components for successful professional performance. As the challenges in the Maritime logistics and Transport field increase, where the efficiency of processes depends on making the right decisions promptly, communicating cross-culturally, and responding adaptively in unpredictable situations, the development of students’ soft skills and English language competence is essential. Consequently, the Maritime logistics education should make a significant focus on them.

The research aims to explore the importance of soft skills integration in logistics education, where language, communication and collaboration skills are defined as quantifiable competencies.

The research methodology is complex and draws on quantitative and qualitative data analysis and a literature review. An online survey among national and international stakeholders and a student-centred survey were applied, and in-depth and SWOT analyses were conducted.

The study concludes the certainty of soft skills and language-based communicative skills inclusion in the learning process that substantially affects professional preparedness, competitiveness in the job market, and effective performance in real logistics environments. Improving these skills will not only ensure the safety of maritime operations, but also contribute to Georgia's economic integration into international transport networks.

Aligning Academic Curricula with the Digital Demands of Autonomous Maritime Transportation

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Keywords: MASS; ROC; Maritime Education and Training (MET); BIP; digital competencies

Rapid technological shifts in autonomous shipping are reshaping global fleets. Rather than reducing human labor, AI and autonomous systems have increased the demand for highly skilled personnel (Sharma et al., 2025). Following EMSA (2023) recommendations and the non-mandatory MASS Code, STCW training serves as a necessary baseline for autonomous ship operators. This creates an urgent requirement for METIs to modernize curricula to accommodate these new roles (Kuntasa et al., 2024).

This paper presents the results of a coordinated initiative involving four European METIs to develop a Blended Intensive Programme (BIP), namely: Barcelona School of Nautical Studies, University of South Eastern Norway, Antwerpen Maritime Academy and University of Zadar. Originally implemented as a pilot program in the second semester of the 2024-2025 academic year, the initiative has now transitioned into a second edition. This updated iteration features an improved course taxonomy (Bokern et al., 2025) and incorporates the World Maritime University as a strategic partner. This collaboration is designed to provide deeper insights and more robust training regarding the digital competencies of seafarers, specifically tailored for the complexities of autonomous operations (Tran et al., 2023).

The study adopts an exploratory, practice-informed qualitative design (Guest et al., 2014; Miles et al., 2014) to bridge the gap between industry requirements and educational delivery. By synthesizing existing research (Campos et al., 2025; Belabyad et al., 2025; Saha, 2023) with new semi-structured interviews from ROC managers and operators, the research addresses three critical areas: i) the definition of tasks and teamwork patterns in port and short-sea MASS operations, ii) the alignment of provider-emphasized competencies with current academic proposals and iii) the translation of these requirements into curriculum and simulator-based assessment design.

Findings indicate that while core clusters such as system understanding, human factors, and communication are well-represented in current research, industry providers place greater emphasis on context-specific demands. These include multi-vessel management in confined waters, screen-based situational awareness, and coaching-oriented communication. The study concludes that METIs must complement generic MASS modules with specialized ROC training to address the unique challenges of inland and port traffic. These insights serve as a roadmap for the standardization of training programs and the establishment of international recommendations for maritime education in the era of autonomous systems.

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Basic Principles of Professional Maritime Sociolect Formation

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Keywords: maritime sociolect; maritime English; speech-effort economy principle; abbreviations; SMCP

Maritime English functions as a specialized sociolect tailored for efficient intercultural communication among seafarers, incorporating maritime terminology, professional jargon, slang and standardized abbreviations within SMCP frameworks. This study systematically catalogues the professional lexical repertoire, emphasizing the speech-effort economy principle operating across phonological, morphological, syntactic and lexical dimensions to streamline linguistic structures and minimize cognitive demands.

Key distinctions emerge between neutral terms, object-naming nomens, stylistically marked professionalisms and expressive jargon, all contributing to reduced linguistic chains that enhance clarity in safety-critical maritime operations. Sociolect formation reflects underlying social dynamics, group identity and lexicon evolution, systematically diverging from general English norms.

The analysis establishes a foundation for advanced multi-level linguistic investigations with proposed future focus on phonetic-level economy to optimize articulation efficiency in professional discourse. This research uniquely integrates the speech-effort economy principle as a cohesive analytical framework, addressing gaps in systematic studies of maritime communication and offering benchmarks for cross-professional sociolect comparisons.

Developing Global Skills through ELT Classes for Maritime Cadets

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Keywords: global skills; English language teaching; maritime cadets.

The present paper examines the integration of essential global skills through English Language Teaching to maritime cadets. In the rapidly developing maritime industry, the demand for skilled professionals equipped with essential global skills has never been greater. English Language Teaching (ELT) classes for maritime cadets play an important role in nurturing global competencies, preparing cadets to thrive in the dynamic and interconnected world of maritime operations. In contemporary education there is a growing understanding that traditional academic knowledge alone is insufficient for learners' successful development. Students need to acquire a set of transferable skills that support lifelong learning and enable them to adapt to the demands of a constantly changing world. Global skills are widely recognized as essential competencies that allow professionals to actively engage in the realities of the 21st century and to function successfully in unpredictable professional contexts. By developing global skills through English Language Teaching classes teachers try to equip maritime cadets with practical abilities that extend beyond language proficiency. Such skills help learners become adaptable in their future maritime international working environment. As a result, cadets become better prepared to navigate the challenges of the maritime industry, communicate effectively with stakeholders from diverse cultural backgrounds, collaborate efficiently with multinational crews and demonstrate the intercultural awareness necessary in a globalized professional setting.

The study outlines methodological approaches that can be applied in ELT classes in order to support the development of global skills among maritime cadets. These approaches provide practical strategies for preparing them to successfully manage both the challenges and opportunities that characterize the modern maritime sector.

The main objective of this study is to review the role of the global skills development through ELT classes for maritime cadets, in addition to improving language proficiency, ELT instruction can serve as an effective platform for cultivating competencies required in the contemporary maritime workplace. The study presents global skills within five interconnected clusters which can be applied to ELT classes: communication and collaboration, creativity and critical thinking, intercultural competence and citizenship, emotional self-regulation and wellbeing, digital literacies (Global Skills: Creating empowered 21st century citizens, Oxford University Press). The skills included in each cluster support one another and can be integrated into ELT pedagogical practices. Classroom activities prepared by the teacher to support the development of global skills can be incorporated into a wide variety of language learning tasks. This allows English language teachers to introduce global skills in a gradual and sustainable manner that is appropriate for both teachers and students.

In conclusion, the English language classes provide an effective environment for fostering global competencies. The integration of language learning with global skills development during the teaching process helps maritime cadets acquire the abilities required for academic success as well as for their future professional careers in the international maritime industry.

Regulatory and Training Challenges in Implementing Nuclear Propulsion for Shipping

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Keywords: nuclear propulsion; shipping decarbonization; sustainability; maritime education and training

The IMO's 2023 strategy on the reduction of greenhouse gas emissions (GHG) constitutes a significant challenge for deep-sea shipping, as currently available zero-emission solutions are unable to meet the high energy demands of long-distance maritime transport (Díaz-Secades, 2024; International Maritime Organization (IMO), 2024). Among the potential alternatives, nuclear propulsion has re-emerged as a technically viable option capable of delivering near-zero greenhouse gas emissions at the required power levels.

Recently, the development of modern generation IV nuclear reactors has the possibility of eliminating many of the challenges and difficulties associated with older pressurized water reactors (PWRs) (Freitas Neto et al., 2021). These new types of reactors have also reignited the debate on nuclear propulsion as a solution to deliver zero-GHG-emission fuels for shipping (Emblemsvåg et al., 2025). An example of renewed interest in nuclear power is the NuProShip project, funded by the Norwegian Research Council, which aims to investigate nuclear propulsion for shipping (Hildre et al., 2025). An important part of the project is to examine the crew's competence, staffing levels, and organizational structures. These aspects will have a large impact on any future transition to nuclear propulsion in deep-sea shipping, yet they remain insufficiently addressed in current Maritime Education and Training programmes (MET).

Nuclear-powered ships are subject to a dual regulatory regime, combining maritime regulations developed by the International Maritime Organisation (IMO) with nuclear safety requirements largely derived from the International Atomic Energy Agency (IAEA) standards. At the same time, these frameworks provide high safety assurance, their combined application results in particularly demanding requirements regarding competence, skills and training. For operational personnel on nuclear ships meeting both requirements, the level of education and amount of training can be quite extensive and challenging compared to conventional merchant ships (Morland and Schøyen, 2023).

Standard training requirements for seafarers are covered in IMO's STCW Convention, where nuclear technology is not directly covered. However, in 1981, IMO released a resolution called the Code of Safety for Nuclear Merchant Ships (Resolution A.491(XII)). This resolution was intended to serve as a guide for flag states implementing regulations on nuclear propulsion and to combine the requirements of the IAEA and IMO's STCW. Considering that this code is outdated, IMO started recently the work of code revision. The revision will ensure that the Code of Safety for Nuclear Merchant Ships is not limited to designs of PWRs with direct-steam-cycle propulsion systems but will adequately address recent advances in nuclear technologies (International Maritime Organization (IMO), 2026).

This paper addresses these challenges through a case-based analysis of a merchant vessel concept equipped with nuclear propulsion, with the aim of examining training needs, competence requirements, crew size and onboard organization under the current regulatory framework. The study seeks to identify key gaps in existing training structures and discuss their implications for the development of future MET programmes.

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A comparative Study on the Use of VR and Actual Machinery in Teaching Centrifugal Pump Operations to Marine Engineering Students

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Keywords: virtual reality; maritime education and training, comparative study

This study employed a quasi-experimental comparative design to evaluate the effectiveness of Virtual Reality (VR) versus actual machinery in training marine engineering students for centrifugal pump operations. A mixed-methods approach was adopted to enable a comprehensive comparison of the two instructional modalities. A sample of 39 Indian students with a background in Mechanical Engineering was divided into two groups, which were subsequently subdivided into two more groups using either VR or actual physical machinery. Their performance was analysed by collecting both quantitative and qualitative data. The quantitative data were collected through standardized written multiple-choice and oral assessments administered by an external assessor, and Likert-scale feedback forms. On the other hand, the qualitative data were gathered through evaluation forms and focus group discussions. Quantitative findings revealed comparable learning outcomes between the two groups, with only a marginal difference of 1.25% in mean assessment scores, indicating that VR training is nearly as effective as physical equipment in conveying technical knowledge. Despite the said marginal difference, VR users reported higher overall satisfaction and clearer conceptual understanding, while physical equipment users rated realism and instructor guidance marginally higher. On the other hand, qualitative analysis revealed that VR was effective for procedural sequence learning and safety, allowing a consequence-free “trial and error”. However, it lacked tactile realism, causing component identification challenges and occasionally fostering passive learning due to over-reliance on visual prompts. Conversely, physical training was essential for developing sensory-motor skills, though it was constrained by safety risks and restricted repetition and access to equipment. In conclusion, VR and physical equipment produced distinct yet complementary learning experiences, and neither should be used in isolation. Students strongly favor a blended, sequential training approach integrating both modalities: beginning with theory lectures inside the classroom, followed by VR for procedural familiarization and error management, then transferring to actual machinery practice for sensory-motor skills development and ending again with VR for repetition to enable mastery. This blended approach optimizes safety, procedural accuracy and mastery, and real-world technical competence, which can be a model in Maritime Education and Training (MET) in general. Future work and research should include re-designing the exercise blending both modalities and testing this blended-mode to determine its effectiveness.

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Effectiveness and Efficiency of Co-operation between IAMU Member Universities: A SWOT Analysis

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Keywords: co-operation; maritime; SWOT; universities

The maritime domain is an international industry, where sustainable global collaboration in development and implementation of education and training (MET) of its workforce is essential. Within the modern context, co-operation should also be sustainable.

IAMU's primary goal is to convene MET institutions to establish a global forum for maritime education and research. To do that, IAMU funds and supports various projects, develops several working groups on significant issues, and hosts annual events such as academic conferences. Over the years, the IAMU-supported co-operation has fostered one-to-one collaboration among IAMU member universities.

This shows that the IAMU's actions and policies have many facets that go beyond the IAMU's defined scope and is greatly affecting the member universities involved. However, although essential, the causal effects of IAMU's efforts and their consequences in developing the collaborations of its members have not yet been evaluated. To develop a better understanding of IAMU policy and action on these cooperations, we developed a study on effectiveness and efficiency of co-operation between the IAMU universities. In our study, we utilized the SWOT (strengths, weaknesses, opportunities, and threats) as a suitable framework for organizational analysis within its operational environment. The S and T are scrutinizing internal aspects of the organization, and the O and W are assessing the external ones, respectively (Bamford 2024, p. 42). The scope of our study is comprehensive, encompassing IAMU-supported activities all the way to one-to-one co-operation of member universities. The SWOT was done within aspects of sustainability. One way of defining sustainability uses the Triple Bottom Line (TBL) concept, where a sustainability framework assesses business performance based on economic, societal, and environmental impact (Elkington 1997).

In this paper 1) Strengths, Weaknesses, Opportunities, and Threats of co-operation between IAMU universities in a global context were studied 2) the general SWOT with experiences from two IAMU members, i.e. Satakunta University of Applied Sciences (SAMK) and the Australian Maritime Collage (AMC) were compared, 3) the most efficient ways to improve co-operation within the aspects of sustainability were defined, and 4) practical guidance for IAMU member universities on international co-operation was developed. The methods used were a literature review, workshops between SAMK and AMC, and semi-structured interviews with faculty from IAMU universities.

The results reveal the major (internal) strengths and threats of IAMU co-operation, as well as (external) opportunities and threats that exist. The SWOT results were also grouped by sustainability aspects. Social aspects were the most common among all SWOT categories.

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Psychological Well-Being and Welfare Needs of Georgian Seafarers. A Cross-Sectional Survey Study

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Keywords: Georgian seafarers; psychological well-being; occupational stress; welfare; mental health

As a keystone of international trade, the global maritime industry relies heavily upon a dedicated workforce of seafarers who must navigate the profound challenges inherent to their profession. Within this context, psychological well-being and access to adequate leisure and healthcare provisions are paramount factors influencing retention, maritime safety, and operational efficiency; however, these elements are frequently overlooked. This study provides an empirical examination of the psychological conditions experienced by Georgian seafarers during their periods of service. Furthermore, it comprehensively explores their expectations regarding the substantive improvement of rest and health provisions, offering a significant, regionally specific contribution to the broader discourse on maritime welfare. These considerations have gained heightened relevance since 2020, the year Georgia officially acceded to the MLC, 2006.

A cross-sectional survey methodology was employed to gather insights directly from Georgian seafarers actively engaged in maritime service. The research comprised a meticulously structured questionnaire of 33 items, designed to elicit detailed responses across several key domains: demographics, professional sea-faring experience, perceived challenges encountered both at sea and ashore, the nature of social interactions, self-reported psychological well-being, and perspectives on industry improvements relevant to Georgia's maritime sector. The questions were designed to capture nuanced perspectives on mental health stressors, coping mechanisms, satisfaction with onboard living conditions, and the impact of maritime life on personal and familial relationships. This comprehensive approach established a robust framework for assessing the multifaceted nature of seafarer life.

The findings illuminated critical insights into the psychological landscape of Georgian seafarers. A significant proportion of respondents reported elevated levels of stress, loneliness, and anxiety, primarily attributed to prolonged separation from family, communication barriers, and demanding operational environments. Such conditions were frequently linked to the quality of onboard leadership, peer support networks, and the perceived fairness of employment conditions. The data unequivocally highlighted a strong desire for substantial enhancements to leisure facilities, specifically increased access to reliable, internet, a wider range of recreational options, and more frequent, meaningful shore leave. Concurrently, participants raised concerns regarding health provisions, calling for improved access to qualified medical care, higher nutritional standards, and robust mental health support services tailored to the unique challenges of the maritime profession. These findings underscore a pressing need for interventions that address holistic well-being.

In conclusion, this survey provides a vital empirical foundation by detailing the psychological and morale challenges confronting Georgian seafarers and articulating their aspirations for improved living conditions. The results emphasize the necessity for concerted efforts from shipping companies, maritime authorities, and national support organizations in Georgia to implement targeted strategies. Priority should be given to enhancing onboard connectivity, diversifying recreational amenities, facilitating regular shore leave, and bolstering mental and physical health support systems. Addressing these critical areas is not only an ethical imperative but also fundamental to fostering a sustainable, resilient maritime workforce, ensuring retention, and upholding the safety and efficiency of global maritime operations.

The Impact of Digital Connectivity on the Psychosocial Well-being and Mental Health of Seafarers: A Medico-Sociological Study

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Keywords: seafarer mental health; digital connectivity; technostress; psychosocial well-being; maritime policy

This research will address the issue of “human-centered digital oceans,” and investigate the effects that both positive and negative have on the maritime workforce created by the use of satellite connectivity. Historically, seafaring was characterized by “forced isolation.” The ship served as a “total institution” In this type of setting, the crew required significant amounts of solidarity among themselves because there were no external sources to provide support. High speed internet has allowed the removal of this form of isolation. It has also replaced it with “virtual co-presence,” which has dramatically altered the medico-sociological environment of living at sea. While the accessibility of high-speed internet is often thought of as a way to combat the feelings of loneliness experienced by many seafarers, this research examines the developing pathologies and social disintegration caused by the development of “always on” cultures. While the maritime industry has reached a digital tipping point, the psychological costs of creating a “permeable ship” remain largely unexplored. Although the Maritime Labor Convention states that internet access is a right afforded to all seafarers, the psychological consequences of this access are still unknown. The study has identified a “digital paradox.” As seafarers become more digitally connected to their lives on land, they become increasingly disconnected from their immediate environments while onboard the ship. This shift has far reaching impacts for mental health and can include chronic sleep deprivation and the erosion of the traditional shipboard social community known as the “social safety net.”

Medico-socially, the research examines “technostress” and its effects on circadian rhythms. Socially, the research uses the concept of “absent presence” to explore how seafarers manage the emotional work of two distinct realities simultaneously.

The research employed a concurrent triangulation mixed-methods research design. A quantitative component of the study involved conducting a global survey of 1200 seafarers to determine depression and anxiety levels using the PHQ-9 and GAD-7 scales. The qualitative component of the study consisted of 40 semi-structured interviews and “digital diaries” that captured the lived experiences of “cabinization”—when the crew members withdraw into private digital spaces at the expense of interacting communally.

A Needs-Based Upgrade of Maritime English Syllabus: Integrating Human-Related Issues

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Keywords: maritime English; syllabus upgrade; seafarers' training; human-related issues

As technological innovation is rapidly introduced to provide the maritime industry with sustainability, enhance maritime safety, and protect the marine environment, the human element remains the key factor that determines whether the industry performs efficiently or fails to achieve the desired goals. The safety of the ship, her cargo, and environmental protection have dramatically depended on a human's ability to analyze the information, evaluate the risks, make quick and right decisions, build the action plan, and communicate it to the other people involved.

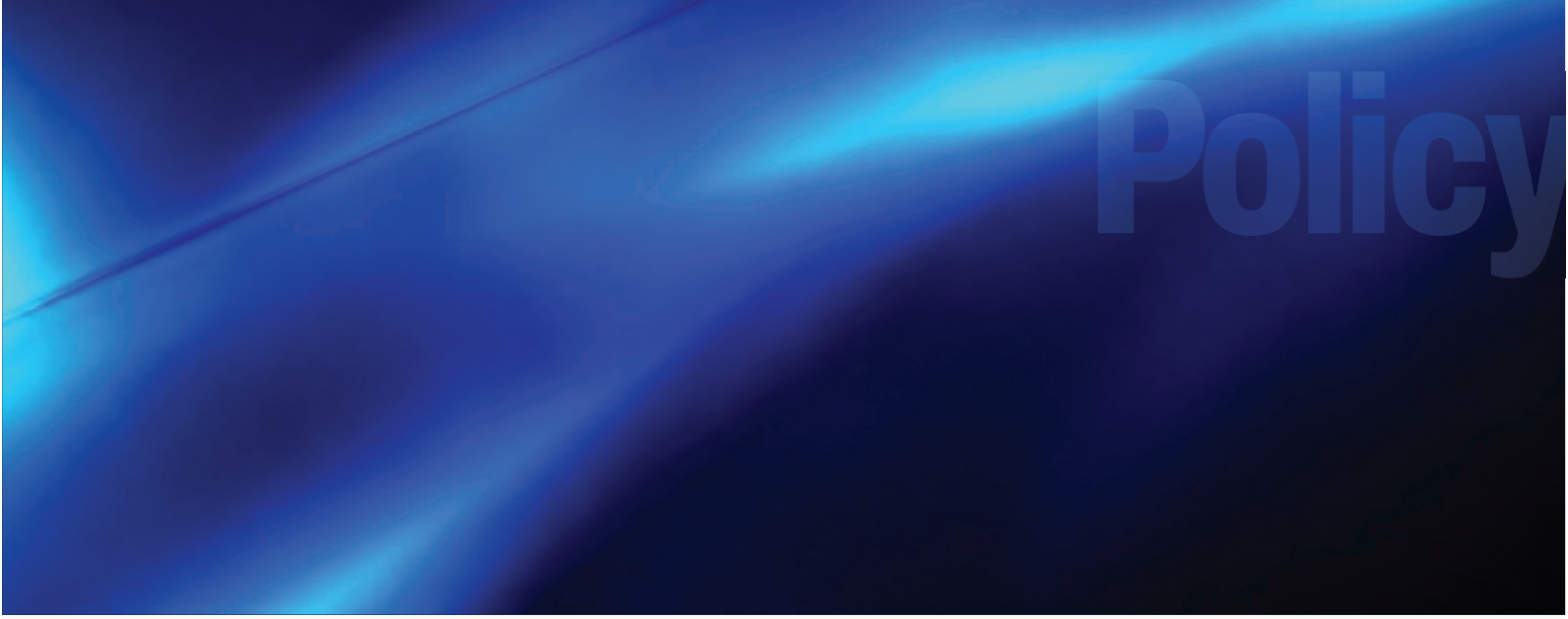
Being a complex multidimensional issue, the human element needs to permeate the entire realm of seafarers' training, as this necessitates a deeper understanding of the required skills, proficiency, knowledge, and traits that maritime professionals need to possess. The enormous potential for envisaging those tendencies in tandem with industry partners and then incorporating the devised content into thoroughly tailored syllabi might be found at maritime education institutions.

The Maritime English course has miscellaneous opportunities for students to gradually immerse themselves in understanding the human element and the leaders' role in decision-making, organizing teamwork, threat and error management. It also promotes the development of essential human skills, such as kind leadership, critical thinking, decision-making, risk assessment, fostering a just culture, and the like. Another advantage is the possibility to change the syllabus relatively quickly to react to the changes occurring in the vision and practice of managing onboard crew life.

Building on these opportunities, the authors have designed and implemented the Maritime English syllabus that primarily focuses on mastery of communication skills through embedding human skills development.

To get the most beneficial learning outcomes, undergraduates have been chosen as the focus group for implementing the upgraded syllabus. Having studied a series of profession-specific subjects and been on shipboard practice, undergraduate students, especially at the Master's level, are apt to analyse and evaluate the significance of the human element in the crewmembers' everyday interaction.

Additionally, the authors share their expertise and provide practical insights into enhancing professional communication effectiveness by addressing human element issues.



Policy Topics

Salvage of Remotely Operated Autonomous Vessels – Who Is Entitled to Salvage Reward According to the Salvage Convention and the Law of Salvage

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Keywords: law of salvage; salvage contracts; autonomous vessel; remote operation; salvage reward

Law of Salvage has ancient roots in Law of Rhodes from which it was found by the Romans who organised it to be based on principles like Negotiarum Gestio and Versio in rem. Law of Salvage was developed from principles to national laws and harmonized later by two international Salvage Conventions in 1910 and 1989.

Salvage agreements became more common in the late 1800s with the introduction of steam and engine-powered tugboats, and the first versions of the LOF standard agreement were introduced already at that time. In the case of unmanned vessels (previously mainly barges) and abandoned vessels, the right to the reward was granted to the salvor who was the so-called “first salvor”. Based on the right of the first salvor, salvage operations were initiated on the salvors own initiative and if they succeeded in them (No Cure – No Pay) they were entitled in salvage reward. The owner or representative of the salved vessel had to refuse the help of the salvor who arrived at the scene. However, if the vessel was not manned, a representative was needed to handle the refusal, expressing the negative will of the owner that his vessel would be salved – Otherwise the salvor who was first in place to start salvage operations would be entitled to salvage reward. The possible refusal was often due to the fact that the owner of the abandoned vessel had already signed an agreement with the owner of the ship on its way to salve the vessel.

How can an autonomous ship that is in danger choose its salvors? Or is it the salvors' free game? Previously, it was required that a ship that has been abandoned can be salved by the first person to arrive at the scene to start rescue operations. How is a ship that moves independently considered abandoned? The crew of an abandoned vessel is normally not considered to be entitled to a salvage reward for salving their own vessel, unless the master has ordered the vessel to be abandoned and the crew has left the vessel without the hope of returning to it. How should the actions of the crew in and from the remote control centre and the right to the salvage award be assessed with regard to a remotely controlled vessel? Are they entitled to a salvage reward after losing contact with the ship? Are they entitled to a salvage reward only when they physically board a ship for rescue purposes or when they land from a helicopter? Does the same ROC apply to an engineer who takes care of the ship's technology from a remote control center? or the owner of the cargo assists in salving his/hers own cargo by providing expert information/assistance? Is the task force sent to repair the ship's systems on site entitled to a salvage award and share of the ship and its cargo?

The crew's share of the salvage award for the salvaging vessel is determined in accordance with rules of the Maritime Act. How are these rules interpreted if the crew operates from one or more remote control centres? How is the reward distributed in such a situation when the salvage is carried out by another remotely operated vessel (e.g. sister vessel) that may be steered by the same remote operator as the vessel to be salved. The salvage regulations have clearly not been thought through to the end with regard to remotely piloted vessels. The article seeks answers and interpretations to the above questions.

Assessment of the Effectiveness of the MLC 2006 in Enforcing Seafarers' Rights in the Global and Digital Labour Market

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Keywords: maritime labour governance; MLC 2006; human-centred shipping, Port State Control

The Maritime Labour Convention, 2006 (MLC 2006) is one of the key instruments of global public policy in the field of protection of workers' rights and the working and living conditions of seafarers. It is commonly described as the fourth pillar of the international regulatory framework of modern shipping, alongside the SOLAS, MARPOL and STCW conventions. MLC 2006 was adopted in response to the fragmented and largely ineffective system of earlier International Labour Organisation regulations, which consisted of more than 65 conventions and recommendations with limited ratification and weak enforcement mechanism. The Convention established global minimum requirements concerning employment conditions, working hours, accommodation, medical care and repatriation, thereby giving practical effect to the concept of "decent work" at sea.

This article examines the effectiveness of the MLC 2006 in enforcing seafarers' labour rights in a global and increasingly digitalised labour market at sea. The analysis consider both the normative structure of the convention and the practical mechanisms for its implementation, with particular emphasis on the ship certification system and the role of Port State Control as a key enforcement instrument. Special attention is given to structural challenges arising from the globalisation of shipping, including the widespread use of flags of convenience, multi-jurisdictional ship-owning structures and the presence of multinational crews. These factors are assessed in terms of their impact on the actual ability of the MLC to ensure a uniform level of protection of seafarers' rights, irrespective of the ship's flag.

The empirical basis of the study is a comparative analysis of data derived from regional Port State Control reports. This approach allows for the identification of recurring areas of non-compliance with the requirements of the MLC, as well as regional differences in the intensity and effectiveness of enforcement of maritime labour standards. The findings suggest that, despite a high degree of formal harmonisation of legal regulations, the practical effectiveness of the MLC 2006 remains constrained by persistent implementation bottlenecks. These shortcomings are particularly evident in the areas of seafarer recruitment, supervision of employment conditions, and the operation of complaint and liability mechanisms.

The findings indicate that further strengthening the effectiveness of MLC 2006 requires moving beyond an approach focused solely on legal and control-based instruments. An important element of public policy aimed at the effective enforcement of seafarers' labour rights is the systematic involvement of universities and maritime training centres in the process of implementation of the Convention. In particular, this concerns the development of education in the fields of seafarers' working and living condition, institutional responsibility and the practical use of available protection mechanisms. At the same time, the increasing reliance on digital recruitment platforms and remote management structures contributes to a growing information asymmetry between shipowners, intermediaries and seafarers. This asymmetry weakens the enforceability of labour standards and limits the effectiveness of the MLC 2006 as an instrument of global maritime labour governance.

Fairness Culture in Maritime Sector: Bridging the Legal and Digital Divides in Near-Miss Reporting

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Keywords: maritime safety; marine policy; fairness culture; near misses; semi-structured interview

The growing emphasis on safety culture in maritime sector has not been matched by a coherent legal framework that operationalizes a fairness culture and protects good-faith reporters. This paper examines how fairness culture is constructed, interpreted, and constrained within existing maritime legal and institutional arrangements through semi-structured interviews with maritime authorities, shipping-company managers, and front-line seafarers. Findings show that international instruments still provide no clear, enforceable definition of "fairness culture", and protections against retaliation for good-faith incident and near-miss reporting remain uneven and weak. Cultural expectations are insufficiently embedded within Safety Management Systems (SMS), while psychological safety and diversity and inclusion concerns are rarely treated as legally protected interests. In parallel, the digitalization of near-miss governance is hindered by non-harmonized data standards, uncertain legal status of electronic reports, limited transparency and contestability of algorithmic decision-making, and slow mechanisms for regulatory updating. Operational constraints and compliance routines further steer practice towards technical conformity, leaving human-factor risks difficult to surface and transform. Consequently, clarifying minimum fairness-culture obligations under the International Maritime Organization framework, strengthening non-punitive and anti-retaliation provisions, and developing a rights-based digital governance framework for near-miss data and algorithms are possible policy options to improve reporting integrity and foster a safer, more inclusive maritime workforce.

AtoN within the Regulatory Framework of Navigation: Evolution from Physical to Digital Navigational Solutions

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Keywords: AtoN; SOLAS; UNCLOS; e-navigation; IALA standards

Aids to Navigation (AtoN) represent one of the fundamental components of the maritime safety system and have traditionally occupied an important position within maritime law. Although long understood primarily as physical means—such as lighthouses and navigational marks—contemporary technological development has led to their expansion into digital and virtual solutions.

This evolution raises a number of legal and regulatory issues, particularly with regard to the normative definition of navigational aids, the allocation of responsibilities among relevant stakeholders, and the capacity of the existing legal framework to adapt to technological change. The analysis of the legal development of AtoN encompasses the SOLAS Convention, which establishes a functional obligation to provide navigational aids without offering a precise definition; the UNCLOS Convention, particularly Article 21, which assigns responsibility for AtoN to coastal States; and the IMO e-Navigation initiative, developed since 2014, which integrates traditional and digital navigational aids into a unified maritime safety concept.

Special emphasis is placed on the key legal challenge arising from the relationship between international conventions, which maintain a technologically neutral approach, and IALA standards, which introduce detailed technical specifications and require implementation at the national level. The normative delineation between the obligations of coastal States regarding AtoN and the responsibilities of shipowners or flag States concerning shipborne equipment largely remains unchanged.

The evolution of AtoN demonstrates the ability of the regulatory framework to preserve technological neutrality and regulatory flexibility, allowing national legal systems to accommodate digital solutions without undermining the fundamental principles of navigational safety.

From Regulatory Scoping Exercise to Governance Architecture: Reconfiguring Legal Governance of Maritime Autonomous Surface Ships in Human-Centred Digital Oceans

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Keywords: MASS; governance architecture; human-centred accountability

This paper argues that MASS regulation represents a reconstruction of governance architecture rather than mere rule adaptation. Drawing on IMO documentation from LEG 106 to LEG 112, including the Regulatory Scoping Exercise (RSE), joint working group outputs and roadmap revisions, the study adopts a policy-oriented institutional analysis to examine how maritime law is being recalibrated to address distributed digital control.

Four governance shifts are particularly evident. First, regulation has moved from identifying potential gaps to developing coordinated institutional design, reflected in strengthened cross-committee collaboration among LEG, MSC and FAL. Second, human authority is preserved through the continued requirement of a legally designated natural-person master, with responsibility shifting from direct onboard command to institutional oversight. Third, liability governance is evolving into a layered structure: external responsibility toward third parties remains centralised to maintain legal certainty, while operational risks are increasingly distributed among remote operators and system actors. Fourth, jurisdiction is extending beyond territorially concentrated supervision toward cooperative, networked oversight of cross-border remote operation centres.

From a policy perspective, the IMO's approach to address MASS issues does not eliminate the human dimension of maritime law; rather, it redistributes authority within digitally networked infrastructures. Automation changes the mode of control, but it does not remove accountability. The regulatory response illustrates that technological autonomy and a human-centred legal order can coexist within a coherent governance framework.

Aligned with the vision of human-centred digital oceans, this study suggests that maritime policy must evolve toward system-oriented regulation while preserving core commitments to accountability, safety and professional competence. For maritime administrations, regulators and educational institutions, the emerging governance architecture signals the need for a shift in regulatory mindset and professional competencies. MASS regulation therefore offers not only a framework for autonomous shipping, but also a broader model for governing AI-enabled transport systems while maintaining a human-centred legal order.

Risk Factors Affecting the Interaction Dynamics Between Maritime Pilots and Tug Masters within Vessel Traffic Services

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Keywords: VTS; human factor; digital decision support systems; situational awareness; effective coordination; maritime safety

Vessel Traffic Services (VTS) play a vital role in ensuring safe and efficient navigation in the maritime sector. The effectiveness of these services directly depends on the quality of coordination between maritime pilots and tugboat masters. However, the interaction between these two professional groups is influenced by various risk factors.

This study aims to examine the risk factors influencing the interaction dynamics between pilots and tugboat masters within the scope of Vessel Traffic Services (VTS). Effective coordination between pilot and tugboat captains is critically important for ensuring safe navigation and operational efficiency at Straits and Channels.

The research encompasses human factors such as experience, communication, and decision-making, as well as operational factors including environmental conditions, heavy vessel traffic, and the reliability of technical systems. Using a mixed-methods approach that integrates literature review, expert interviews, and risk assessment analyses, the main risk factors were identified and evaluated. The findings of this study are expected to contribute to the enhancement of maritime safety management within VTS operations, improve operational protocols, and support evidence-based risk mitigation strategies.

Designing an Industry Advisory Board for Global Maritime Education: An Action Research–Based Organizational Development Model for the IAMU

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Keywords: industrial advisory board (IAB); organizational development; maritime education and training (MET); university-industry collaboration

The International Association of Maritime Universities (IAMU), as a global network of maritime higher education institutions, is expected to maintain close and effective relationships with the maritime industry to ensure that education, training, and research remain aligned with technological, environmental, and workforce demands. In line with the IAMU Tokyo Statement, this study presents action research–informed organisational development (OD) initiative to design, establish, and evaluate an Industrial Advisory Board (IAB) as a structured mechanism for sustained industry engagement.

The project adopts a cyclical action research framework consisting of four phases: appraisal, planning, execution, and monitoring. The appraisal phase critically examines the IAMU's current organizational structure, existing practices, and expectations concerning industry collaboration through document review and stakeholder consultation. The planning phase focuses on co-designing the IAB, defining its mandate, membership profile, governance structure, and operational procedures through iterative engagement with the IAMU leadership and stakeholders. The proposed execution phase involves piloting the IAB, while the monitoring phase introduces a systematic evaluation approach utilizing qualitative inquiry and performance indicators to assess perceived value, operational effectiveness, and areas requiring improvement.

By integrating organizational development theory with action research and stakeholder-based governance, this study offers a transferable model for embedding industry advisory mechanisms within international higher education associations. The findings are expected to support the IAMU's long-term institutional capacity building and contribute to the development of more responsive, human-centred, and future-oriented maritime education systems.

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A Simulation-Based Training Curriculum Design for Port Radio Operators in Japan

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Keywords: VTS; simulation-based training; port radio operations; maritime English

The main goals of Vessel Traffic Services (VTS) are to reduce navigational risks and optimize port operation efficiency by integrating multifaceted systems of radar technology, surveillance sensors, VHF communications, traffic signals, and skilled human operators (IMO, 2021). First implemented in the 1940s and 1950s in Europe, and officially recognized and standardized by the International Maritime Organization (IMO) in the 1980s and 1990s through instruments such as Resolution A.857(20) and its successor Resolution A.1158(32), VTS have become a crucial component of global maritime safety infrastructure (IMO, 2021; Uyà Juncadella & Martínez de Osés, 2020). One vital element of VTS operations is the Port Radio Operator (PRO), those who conduct shore-to-ship port communications by utilizing standardized voice procedures via VHF transmissions to transfer critical information in real time. PROs employ IMO Standard Marine Communication Phrases (SMCPs) and Global Maritime Distress and Safety System (GMDSS) protocols to minimize ambiguity while serving as a conduit to help traffic safely navigate ports and respond to emergency situations (IMO, 2021; IALA, 2022a).

Japan, with its numerous high-density waterways, complex coastal topography, and strategically significant ports, requires an efficient VTS regime supported by highly trained and competent PROs who form the frontline of shore-to-ship voice communications (MIC, 2025). PROs must command a vast set of knowledge and skills including proficiency in maritime English, situational awareness, regulatory knowledge, and rapid decision-making to carry out their duties with a high degree of competence. Developing and maintaining these competencies entails sophisticated training techniques that go beyond traditional classroom instruction (IALA, 2022b; IALA World Wide Academy, 2025).

This paper examines Japan's VTS landscape, outlines the competencies required of active PROs, and details a simulation-based training methodology currently employed to develop and refine their operational skillset. The training program outlined in this paper utilizes real-time scenario-driven simulations in which operators, while monitoring Automatic Identification System (AIS) displays, must respond to dynamically developing emergencies and operational complications across various Japanese ports (JRC, 2025). Training scenarios encompass a wide range of situations that PROs may encounter, including but not limited to vessel groundings, medical emergencies aboard vessels, drifting and not-under-command (NUC) vessels, vessels straying from designated traffic lanes, and non-compliance with port traffic regulations. These simulations are designed to cultivate critical thinking, improve communication accuracy under pressure, develop communication strategies when dealing with distressed vessels and crew, and reinforce adherence to standardized phraseology and procedures.

The paper further discusses the alignment of the training curriculum with the IALA V-103 model courses for VTS operator training and IMO communication frameworks, including SMCP and GMDSS requirements (IALA, 2022a; IALA, 2025). Current implementation practices are evaluated alongside future directions for training development, which include expanded use of simulation technology, enhanced maritime English language proficiency assessment, integration of digital tools and e-learning platforms, and other emerging technologies and practices that can augment operator performance and training outcomes.

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A Framework for Instructor Competency Criteria in Simulator-Based Maritime Training

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Keywords: maritime simulator; instructor competency; simulator-based training; technical skills; non-technical skills

Simulator-based training has become widely used in high-risk industries such as maritime and aviation. While advanced simulator systems support realistic training conditions, the effectiveness of training largely depends on the instructor. In many cases, instructor competency is described only in general terms, focusing on experience or certification, without clearly specifying the skills required during simulator-based exercises.

This study proposes a framework for instructor competency criteria in simulator-based training for maritime education and training (MET) institutions. The framework focuses on the combined role of technical and non-technical skills required during the simulator training. Technical skills include understanding simulator systems, scenario setup, system limitations, and the ability to monitor technical performance. Non-technical skills include communication, situational awareness, decision-making, leadership, and workload management.

Rather than treating these skills separately, the framework explains how they are used together during the briefing, execution, and debriefing sessions. Attention is given to how instructors adjust the difficulty of scenarios, observe trainee behavior, respond to unexpected situations, and provide effective feedback after the exercise.

The framework also considers how instructors influence the transfer of learning from the simulator environment to real operational settings. By organising instructor competencies into a clear and practical structure, this study aims to support more consistent instructor development and evaluation. The proposed framework is aimed as a practical reference for MET institutions seeking to improve the quality and reliability of simulator-based training.

Workforce Development for Hydrogen Ports

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Keywords: hydrogen ports; ammonia; methanol; workforce; hydrogen supply chains

Ports serve as critical export and import gateways in the emerging global hydrogen trade, supporting industrial decarbonisation efforts aligned with net-zero ambitions. However, one of the complex operational challenges ports face during their transition into hydrogen hubs is the evolving nature of job roles, which increases the need for advanced safety preparedness and digital competence (Chen et al., 2024). Workforce readiness emerges as a binding constraint, with shortages already evident across clean energy projects (IEA, 2022). Hence, building a highly skilled workforce is critical for ports to ensure the safe and efficient management of hydrogen and its derivative supply chains.

Adopting a human-centred socio-technical perspective, this study identifies the key workforce readiness issues, and the knowledge and technical capability require, as well as practical strategies to strengthen hydrogen port workforce development. It draws on semi-structured interviews with 28 experts from across Australian states and territories, including representatives from ports, industry, government, and training institutions.

The study identifies evolving safety expectations, regulatory ambiguity, and immature competency frameworks that impede workforce readiness by generating uncertainty around skills, standards, and operational procedures. Regulators increasingly require structured training integrated within Safety Management Systems (SMS), but standards remain inconsistent, particularly for ports. New safety design needs comprehensive evaluation, such as consequence modelling, spatial analysis, and scenario analysis, necessitating multidisciplinary expertise that is currently scarce. Labour shortages and competition with higher-paying sectors elevate risk, while unclear accountability for training investment slows upskilling efforts. Fossil-fuel handling skills are only partially transferable, as hydrogen and its derivatives introduce distinct hazards that require specialised training. Persistent STEM and maritime skill deficits threaten long-term capability risks.

This study contributes insights by identifying strategic responses to the workforce challenges include training precincts, the formation of technology partnerships, and the introduction of micro-credentials aligned with project phases. Priority capabilities span product-specific safety, operational competency, engineering skills, emergency response, refuelling procedures, and seafarer standards. Findings show that workforce development underpins port strategy and social licence, requiring nationally consistent frameworks, Indigenous inclusion, and strong education pipelines. Ports shape policy by aligning workforce planning with infrastructure and safety standards. Workforce investment functions as a productivity lever, while human-centred digital tools such as simulations, digital twins, and decision-support systems enhance preparedness when embedded in robust safety cultures.

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Human-Centred Workforce Development for Digital and Sustainable Ports

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Keywords: green and digital transformation; workforce development; sustainable port governance

Ports are simultaneously navigating rapid digitalisation and accelerating decarbonisation obligations. The policy context is increasingly explicit: the IMO's 2023 GHG Strategy commits international shipping to net-zero, with the ambition to uptake zero/near-zero fuels. In parallel, EU Fit for 55 measures extend carbon and fuel-intensity compliance pressures to port calls, including the extension of the EU ETS to maritime from January 2024 and the FuelEU Maritime Regulation (EU 2023/1805), which is applies from January 2025 and sets well-to-wake GHG-intensity limits for energy used by ships calling at EU ports. FuelEU also introduces "zero-emission at berth" expectations for container and passenger ships through on-shore power supply (OPS) or equivalent technologies from 2030 (and broader deployment from 2035), reinforcing the need for ports to deliver both infrastructure and operational competence.

This paper develops a conceptual model and policy roadmap for "policy-ready" green port workforce development, grounded in a structured mapping of (i) global and regional regulatory drivers (IMO 2023 GHG Strategy; EU ETS extension; FuelEU; AFIR-linked OPS obligations) and (ii) voluntary port governance frameworks widely used to operationalise environmental performance and accountability. In particular, the roadmap integrates the EcoPorts Port Environmental Review System (PERS), which is a port-sector-specific environmental management standard aligned with ISO 14001 principles, and the International Association of Ports and Harbors (IAPH) World Ports Sustainability Programme, which curates practice-based sustainability projects across governance, climate and energy, digitalisation, and community dimensions.

The resulting roadmap specifies four capability domains that maritime education and lifelong learning pathways can translate into measurable learning outcomes and micro-credentials: (1) digital operations and data stewardship (e.g., digital twins, AI-assisted decision support, MRV-enabled reporting); (2) decarbonisation and energy transition competence (e.g., lifecycle GHG concepts, fuel/energy systems, OPS planning and safe operations); (3) safety, cyber, and assurance (e.g., supervisory control, incident readiness, data integrity for compliance); and (4) governance and change leadership (e.g., cross-stakeholder coordination, just transition awareness, and continuous improvement mechanisms consistent with PERS/WPSP practices). The model links each domain to policy triggers and to suggested curriculum modules that universities, academies, and port authorities can deliver through stackable, work-based learning.

Pathways to an Environmentally Sustainable Cruise Industry – What Major Cruise Companies Declare and Whether It Is Enough

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Keywords: cruise companies; environmental sustainability; green transition; education; stakeholder engagement

Using secondary data from corporate reports, websites, and other literature sources, this paper analyses the sustainability policies and strategies of major cruise companies, as well as their partnerships, projects, and educational programmes related to environmental sustainability in the cruise sector. It examines whether company efforts alone are sufficient, or if strong partnerships with governments, academia, and local communities are necessary to accelerate the green transition in cruise tourism. The paper highlights the complex interplay among industry practices, regulations, and community attitudes, and emphasises the importance of cruise industry investment in green technology innovations and education both on board and on shore. Numerous examples of good practice demonstrate that an industry once considered extremely negative for the environment and society can operate according to the principles of sustainability and cooperation among all stakeholders. The question of whether the cruise industry can be driven towards effective green transformation by relying on self-regulation and voluntary company-driven sustainability efforts, or whether deeper stakeholder engagement is necessary to facilitate industry transformation, remains open, and further multifaceted analyses are needed.

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Training of Underwater Ship Husbandry (UWSH) Divers in Compliance with Safety Standards and Environmental (Green) Regulations: The Case of Türkiye

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Keywords: underwater ship husbandry; diver safety; diver training; green maritime practices; diving regulations; maritime education

The study examines the education of marine divers in Türkiye, who are involved in Underwater Ship Husbandry in the perspective of occupational safety and environmental sustainability against the risks that they may be possible to face while they are working on the hulls of marine vessels. Underwater Ship Husbandry works carried out by divers play a critical role for vessel efficiency, fuel consumption reduction and safety of the vessel but since the divers exposed to different physical and environmental conditions, they also face significant occupational safety and environmental risks.

The study describes the existing training standards, training structures, sector practices and certification process under the regulatory framework in Türkiye and then identifies the blurred areas in human centered, safety-oriented training system which also pays great attention to environmental issues. To reach the right conclusions, study also analyses the international regulations, standards and sector practices using a qualitative assessment approach. The findings highlighted the need for a training model which is more focused on the importance of diver safety and green maritime awareness.

The study proposes a new training model which is believed to play critical milestone to improve occupational safety of Underwater Ship Husbandry divers and plays a critical role in highlighting environmental sustainability. It's also believed that this study will support the development of safe and green maritime professionals.

Proposed Competence for Seafarers on Ships Using Non-IGF Code Alternative Fuels: Methanol, Ammonia, and Hydrogen

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Keywords: ammonia fuelled vessels; basic training; STCW standardization; eco-friendly shipping

Ammonia leaks on vessels present immediate dangers due to the fuel's acute toxicity (LC50 2,000 ppm) (Masia B, 2024), along with its potential to cause corrosion and asphyxiation (DNV Et al., 2023). The HTW 11 correspondence group noted urgent training needs for ammonia, citing the potential for lethal concentrations in engine rooms during leak (IMO, 2025a), as identified in MSC.1/Circ.1687 (IMO, 2025b). However, current international frameworks are lack of mandatory training standards for seafarers handling these risks, creating a important safety gap.

While the IGF Code and STCW Regulation V/3 provide a robust training regime for ships using low-flashpoint fuels like LNG (IMO, 2010; IMO, 2017), ammonia falls outside this regulatory scope due to its high flashpoint (651°C). Consequently, whereas LNG crews must satisfy specific competency standards, ammonia crews rely on interim guidelines (MSC.1/Circ.1687) that lack comparable mandatory training provisions (IMO, 2025b). Simply extending Regulation V/3 to ammonia is contradictory, as V/3 is explicitly tied to IGF Code applicability.

Recent proposals submitted to HTW 12 underscore this insufficiency, arguing that the current draft interim guidelines (HTW 12/7) ambiguously limit training to seafarers with safety duties (RINA, 2025). Given ammonia's inherent toxicity, it is necessary to review that whether all seafarers should undergo basic training to ensure a uniform fundamental safety. Furthermore, since real-world exposure to ammonia leaks is lethal, traditional in-service training is insufficient for acquiring emergency response skills.

To bridge this regulatory void, this study proposes the establishment of a new section in A-V/4 (following sections should be renumbered), titled "Mandatory minimum requirements for the training and qualifications of masters, officers, ratings and other personnel on ships using alternative fuels not covered by the IGF Code." Under this framework, ammonia-specific standards of competence are developed in Table A-V/4-1. A key feature of this proposal is the mandatory inclusion of simulators including VR/AR/MR-based training in Column 3, ensuring seafarers can safely experience and practice responding to high-risk hazardous scenarios. Table 1 outlines these fundamental competencies to serve as a foundation for flag state approval (Zero Carbon Shipping, 2025a; The Decarb Hub, 2025). Expanding upon this foundation, it further recommends essential standards of competence to be progressively expanded through continuous industry-academia-research collaboration, ensuring that training frameworks evolve alongside technological advancements and operational feedback.

This proposal offers a unified and standardized framework for ammonia ship operations. Future validation through cadet training programmes using simulators including immersive technologies is recommended to ensure global safety consistency (IMO, 2025a).

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Table 1. Specification of minimum standard of competence in basic training for ships using alternative fuels not covered by the IGF Code (e.g., Ammonia)

Competence	Knowledge, Understanding and Proficiency	Methods for Demonstrating Competence	Criteria for Evaluating Competence
Recognize and Mitigate Specific Hazards	Fuel-Specific Hazards: 1. Toxicity limits (IDLH) and symptoms 2. Corrosivity and chemical burns 3. Flammability and explosion limits Health Impact Awareness: 1. Acute vs. chronic health effects 2. First aid (neutralization, eye washing) 3. SDS interpretation for toxic cargoes	Examination and assessment of evidence obtained from one or more of the following: 1. approved in-service experience 2. approved training ship experience 3. approved simulator training, including VR/AR/MR-based simulation for hazardous scenarios 4. approved training programme	Relevant hazards (toxicity, burns) are promptly identified. Immediate mitigation actions are taken per SDS. Symptoms of exposure are correctly recognized.
Execute Emergency Response	Release Scenarios: 1. Bunkering hose rupture 2. Pipe leakage in enclosed spaces Response Actions: 1. Muster/Evacuation (upwind principle) 2. Exclusion zones establishment	Examination and assessment of evidence obtained from one or more of the following: 1. approved in-service experience 2. approved training ship experience 3. approved simulator training, including VR/AR/MR-based simulation for hazardous scenarios 4. approved training programme	Evacuation avoids gas clouds (upwind). Exclusion zones are correctly marked.

Decarbonising Shipping Through Slow Steaming: Emissions, Economics and Legal Trade-offs

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Keywords: slow-steaming; emission reductions; decarbonization; legal aspects; contractual agreements

Maritime transport accounts for approximately 80% of global trade by volume, making it a cornerstone of the international economy and is responsible for approximately 2-3% of global carbon dioxide emissions. Vessel speed has attracted increasing attention as a mitigation strategy for greenhouse gas (GHG) emissions, with the concept of slow steaming (i.e. intentionally reducing vessel operating speed) identified as one of the most effective operational measures to improve fuel efficiency and reduce CO_2 emissions (Psaraftis & Kontovas, 2010; IMO, 2020). Studies consistently demonstrate that a 10% reduction in average speed can yield a huge reduction in CO_2 emissions not only for single vessels but for the entire fleet too, due to the cubic relationship between speed and fuel consumption (CE Delft, 2017). Consequently, slow steaming not only reduces emissions but also lowers bunker fuel costs, a major expense for ship owners. At the same time, it represents one of the easiest emissions reduction measures to implement. It is an operational measure, in that vessels can simply reduce their operating speed without requiring major engine modifications or incurring significant upfront implementation costs.

Slow steaming is not a novel response: it emerged during the 1970s oil crisis, when rising fuel prices incentivised reduced speeds (Stopford, 2005). However, it gained prominence in the early 2000s amid volatile fuel prices and market conditions, and growing regulatory pressure to improve environmental performance. Nevertheless, significant trade-offs exist. Lower operating speeds extend voyage durations, increasing turnaround times, reducing vessel utilisation, and raising inventory and supply chain costs; this is a concern emphasised in classical transport economics (Psaraftis and Kontovas, 2010; Psaraftis, 2019).

The potential for substantial emissions reduction even led to considerations within the International Maritime Organization (IMO) of mandatory speed limits (Psaraftis, 2019). Although the theoretical environmental and operational benefits of slow steaming are well established, less attention has been paid in academic literature to its commercial and contractual implications under standard maritime charterparty agreements. Contractual arrangements between ship owners and charterers often impose obligations, such as the duty to “proceed with all possible dispatch,” which can constrain the selection of operating speeds and expose parties to commercial disputes when slow steaming is employed (Zografakis et al, 2023). Ship owners operating vessels under time charter, voyage charter, or contract of affreightment are therefore legally constrained in their ability to adjust speeds for environmental reasons, in contrast to owner-operators who can make such decisions unilaterally based solely on cost optimisation.

These legal challenges have been acknowledged in industry and academic discourse (Rebelo, 2024; Girvin and Ulfbeck, 2025) For example, BIMCO (the international shipping association) has developed specific charterparty clauses to enable contractual adjustments for slow steaming, not only for economic efficiency but increasingly to comply with IMO regulations such as the Energy Efficiency Existing Ship Index (EEXI) and the Carbon Intensity Indicator (CII) (BIMCO, 2021).

Therefore, in this paper, we quantify the impact of slow steaming on fuel consumption, CO_2 emissions, and economic performance using real-world data from the Clarkson’s SIN database. We then examine the commercial legal issues that arise when slow steaming interacts with maritime contracts, highlighting gaps in

current practice and proposing pathways to reconcile environmental imperatives with commercial and legal realities. Our findings contribute to a more holistic understanding of slow steaming, bridging technical, economic, and legal dimensions critical to policy and industry decision-making.

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Artificial Intelligence–Driven Transformation in Maritime Education and Training (MET): Institutional Governance and Competency Development in Port Operations Practices

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Keywords: maritime education and training (MET); artificial intelligence; port operations; cargo handling practices; institutional governance; digital ports

The maritime industry has been experiencing a digital revolution with recent concepts, such smart contracts, autonomous ships, smart ports, digital twin practices. The impacts of digitalization are expected to continue with enabling new generation artificial intelligence (AI) utilization, which also calls for improved and increased adoption of automation. The overall impact of AI on maritime transportation in the future will be substantial, and therefore, it becomes crucial to have deck and engine officers having the technological thinking in the merchant fleet. Furthermore, the accelerating digital transformation of global port ecosystems characterized by automated container terminals with AI-driven container handling yard optimization, scheduling, berth allocation systems, and digital twin infrastructures have significantly reshaped operational practices in port management and cargo handling systems. This transformation requires a strategic response within Maritime Education and Training (MET), particularly in teaching the skills required for competency areas regarding port operations and cargo management practices.

This study examines the integration of Artificial Intelligence (AI) tools within MET from an institutional governance and competency-development perspective, focusing specifically on their application in port operations and cargo handling contexts. Rather than approaching AI as a purely instructional enhancement and using it just as a teaching aid, the research evaluates how AI-powered analytical systems, decision-making tools, and simulations can be embedded within MET frameworks and programs to ensure education and training matches with digitally transformed port environments.

The proposed AI Integration Framework is structured across four institutional domains: (1) AI-enhanced cargo planning and stowage simulations within MET programs; (2) predictive analytics for berth allocation and terminal resource optimization scenarios; (3) AI-assisted risk assessment and dangerous goods handling analysis; and (4) institutional competency monitoring and governance mechanisms ensuring regulatory alignment with STCW requirements.

To support the conceptual framework, an exploratory empirical study was conducted among maritime faculty members and undergraduate cadets engaged in port-related coursework. Using mixed-method data collection (survey instruments and interviews), the study evaluates institutional readiness, perceived competency development, governance awareness, how well students develop key skills, and ethical considerations associated with AI-supported training environments.

Results indicate that AI-integrated analytical tools significantly enhance students' capability in operational scenario evaluation, cargo optimization analysis, and risk-based decision-making. However, governance-related challenges emerge regarding algorithmic transparency, potential over-reliance on automated systems, and the necessity of structured institutional policies within safety-critical maritime education contexts. Overall, the study concludes by proposing an AI Governance and Institutional Readiness Framework focused on and tailored to MET institutions, positioning AI integration not merely as technological enhancement but as a strategic institutional transformation aligned with the evolving digital port ecosystem and maritime safety standards.

STCW Assessment in the Age of GPTs - Validated Rubrics for Competency Assurance and Digital Leadership

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Keywords: global maritime professionals; rubric-based assessment; digital leadership; human–AI collaboration (GPT-enabled learning); skills

AI-digitalization is changing how ships are operated and how decisions are made, but Maritime Education and Training (MET) assessment has not evolved at the same speed, especially when it comes to measuring digital leadership. Current International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW, 1978, as amended) aligned evaluation practices tend to capture technical task performance, yet often miss how cadets and officers lead in data-heavy, automation-supported environments.

This paper reports results from the research "Updating STCW with rubric-based criteria for evaluation in the context of AI/GPTs - human collaborative MET learning" (AI-MET) study, supported by grant from the International Association of Maritime Universities (IAMU) and Nippon Foundation. It examines what AI means for MET training, assessment, and competency development. The research aims to support the revision of the IMO STCW Code by developing and validating rubric-based assessment criteria that integrate AI and GPT-supported human collaboration in Maritime Education and Training (MET). The aim of the research is to align assessment practices with emerging digital leadership competencies and the evolving needs of the global maritime sector. Authors map the opportunities as more adaptive training, stronger evidence trails for assessment (e.g., learning analytics), and richer scenario-based practice, alongside the threats that can weaken competence and assessment validity, including over-reliance and skill fade, opaque AI behaviour, bias and unequal access etc. Together, these findings highlight where assessment must be strengthened or updated to ensure that digital leadership is evaluated in ways that remain credible, auditable, and aligned with safety and environmental expectations.

Acknowledgements

This research is supported by grant from the International Association of Maritime Universities (IAMU) and Nippon Foundation.

Developing a Polar Shipbuilding Workforce Capacity: Job Task Analysis and Gap Analysis Informed by Global Best Practices

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Keywords: maritime workforce; polar shipbuilding; job task analysis; gap analysis; international collaboration

As we experience sea-ice loss opening previously inaccessible waters, the Arctic has seen a remarkable increase in ship traffic over the past decade transforming the region into an emerging corridor for global trade. In anticipation (or reaction) to this change, many shipping companies and nations are seeking to build polar-ready vessels. Expanding any nation's capacity to design and construct polar-capable vessels requires a highly specialized maritime workforce prepared with skills that extend beyond traditional shipbuilding. As the United States pursues increased icebreaking capability and Arctic mission readiness, workforce shortages across shipyards and maritime trades risk becoming a bottleneck to program execution. As part of the Icebreaker Collaborative Effort (ICE) Pact, a trilateral agreement between Canada, Finland, and the USA, this project is developed leveraging a consortium of U.S. and Finnish universities, vocational schools, and shipyards. This study proposes a structured methodology, grounded in job task analysis (JTA) and workforce gap analysis, to identify the competencies necessary for building and sustaining a polar shipbuilding talent pipeline.

The proposed framework includes a detailed mapping of the technical, digital, and safety-critical tasks required in polar ship construction; identification of current capability gaps within U.S. workforce training pathways; and comparison with established training models in Finland (and potentially Canada and South Korea). The identified gaps will inform curriculum design for U.S. trade schools, industrial training programs, and maritime academies. Initial findings indicate that while U.S. institutions possess strong foundational shipbuilding instruction, gaps exist in ice-class engineering competencies, advanced welding certifications, and integrated digital manufacturing processes. Finnish training models demonstrate effective approaches by embedding cross-disciplinary skillsets, work-based learning, and industry-academia co-delivery of micro-credentials. These insights will guide the development of a modular curriculum emphasizing technical specialization, digital fluency, and alignment with international standards.

This work contributes to the conference theme by identifying the human, technological, and educational requirements for a safe, green, and technologically advanced polar shipbuilding workforce. The analysis will support an evidence-based curriculum design for U.S. institutions and will create a pathway for long-term transatlantic collaboration in maritime workforce development.

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Sustainability Communication and Reporting by Baltic and Adriatic Ferry Operators – Implications for Future Maritime Professionals

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Keywords: maritime industry; ESG reporting; sustainability communication; ferry operators; maritime education

Sustainability communication and reporting have become increasingly significant within the maritime industry, as transparency regarding environmental and social impacts, along with responsible governance, is essential for advancing the sector's transition to sustainable and resilient business models. Ferry operators, as central actors in passenger transport and short-sea shipping, play a critical role in addressing climate action, energy efficiency, safety, and community engagement through their sustainability initiatives and communication strategies. Examining these communication practices is particularly pertinent to the education and training of future maritime professionals, who will be tasked with implementing and managing sustainability strategies within maritime organizations. This study critically examines and compares the sustainability communication and reporting practices of ferry companies operating in the Baltic and Adriatic Seas, with a focus on sector-specific issues. The research employs a qualitative methodological approach comprising two complementary phases: expert assessment and systematic website content analysis. The study assesses the extent to which ferry operators disclose information on environmental, social, and governance (ESG) dimensions, including transparency in reporting, impact monitoring, and the communication of sustainability initiatives.

The findings reveal that ferry operators in the Baltic Sea region exhibit a significantly higher level of engagement in communicating sustainability-related activities than those in the Adriatic Sea region. However, the overall amount of disclosed sustainability information remains limited in both regions. Additionally, the types of sustainability initiatives communicated vary between the two regions, reflecting differences in strategic priorities and communication practices within the ferry sector. These results emphasize the need for more systematic and transparent approaches to sustainability communication and reporting in ferry shipping. From an educational standpoint, the findings highlight the importance of incorporating practical knowledge of ESG strategies, sustainability reporting, and communication practices into maritime higher education and professional training programs to prepare future maritime professionals better to facilitate sustainable transformation in the maritime industry.

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STCW – MLC Matrix for Performance. Assessing Maritime Digital Leadership for Safer and Greener Maritime Operations

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Keywords: digital safety culture; global maritime professionals; skills; human–AI collaboration

Maritime digitalisation is accelerating the use of AI-enabled decision support, automation and data-driven "algorithmic management" across ships and ports. This shift challenges the traditional separation between

(i) competence regulation, anchored in the IMO's STCW Convention and Code, which set international requirements for training, certification and watchkeeping and

(ii) decent work regulation, anchored in the ILO's Maritime Labour Convention (MLC, 2006), which safeguards seafarers' working and living conditions, including work/rest arrangements, health protection and complaint processes

This paper offers a comparative, human-centred analysis of STCW and MLC under digitalisation, arguing that "safe and green" performance increasingly depends on their combined effect: digital competence without decent-work safeguards increases fatigue, overreliance on automation and poor risk communication; decent-work protections without updated digital competence leaves crews underprepared for AI-driven operational complexity and cyber-physical risks. Evidence from shipping digitalisation and automation literature indicates that decision-support and higher autonomy levels reshape training needs and system safety, reinforcing the need for integrated governance and assessment.

Building on the AI-MET approach, in the paper is proposed a STCW × MLC rubric matrix that translates the policy comparison into measurable performance criteria for Maritime Education and Training: rubric descriptors align STCW competence elements with digital-leadership indicators (e.g., data literacy, ethical AI use, systems thinking, communication under uncertainty) and MLC-informed human factors indicators (e.g., fatigue-aware decision-making, workload transparency, wellbeing-oriented teamwork).

Methodologically, the study combines comparative doctrinal analysis of STCW and MLC texts and related guidance with directed qualitative content analysis to identify where digitalisation stresses existing provisions. The matrix and descriptors are then refined through semi-structured stakeholder focus groups and expert interviews with regulators, employers, seafarer representatives, and training/technology actors, analysed thematically to confirm feasibility and regulatory relevance.

The expected contribution is a practical and auditable pathway for regulators to modernise STCW- and MLC-informed guidance for the digital oceans era, clarifying expectations for maritime digital leaders who can work responsibly with algorithmic systems, safeguard seafarer wellbeing, and support safer, greener operations.

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A Physics-Driven Feasibility-Preserving Optimization Framework for Berth Allocation and Scheduling

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Keywords: port operations; berth allocation and scheduling; combinatorial optimization; memetic algorithms; constraint-handling metaheuristics; vessel-berth compatibility

Dynamic berth allocation and scheduling problems (DDBASPs) require coordinated decisions that satisfy physical compatibility constraints while balancing multiple operational objectives. In congested port environments, infeasible berth assignments and unreliable schedules often arise when physical feasibility and reliability requirements are treated as secondary considerations. This study proposes an improved memetic algorithm, termed PD-MA, to address DDBASPs with explicit physical compatibility constraints and reliability-oriented performance objectives. Physical feasibility is ensured through a compatibility-based repair operator that adjusts berth assignments and service start times without modifying vessel or berth attributes. A customized local search operator with adaptive acceptance criteria is incorporated to enhance solution quality. In addition, an adaptive weight adjustment mechanism is introduced to balance waiting time, berth workload balance, operational efficiency, constraint violations, and reliability penalties. Numerical experiments on small-, medium-, and large-scale instances show that PD-MA consistently outperforms several benchmark metaheuristic algorithms in terms of feasibility, cost efficiency, and reliability performance, demonstrating its effectiveness for realistic berth allocation and scheduling applications.

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A Proposal for Improving the Decision-Making Process for Establishing a Traffic Separation Scheme

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Keywords: safety of navigation; traffic separation scheme; decision-making process; machine learning model

Maritime transport plays a key role in world trade, with indications of growth in the coming years (UNCTAD 2024). The increase in trade and cargo volumes leads to higher volumes of maritime traffic and greater traffic density on certain routes, which consequently leads to an increase in the probability of accidents at sea. One way to reduce the risk of maritime accidents and to maintain safe and efficient navigation in specific shipping areas is through a traffic-management route system (Ships' Routeing 2019). This involves the spatial organisation of maritime navigation, specifically the establishment of a Traffic Separation Scheme (TSS). The establishment of a TSS follows the guidelines of the International Maritime Organization (IMO), which do not include a scientific component or a method to support decisions on establishing a TSS (IMO, 2003). Although TSS has been analysed in many professional and scientific publications, it is evident that these mainly focus on optimising existing TSS, rather than improving the decision-making process for its establishment (Run 2013; Serhan et al. 2023). Following the aforementioned and given the importance of keeping safe navigation, it is evident that the existing decision-making process on establishing TSS needs to be appropriately improved.

The research presented in this paper aimed to analyse and determine the criteria that affect or may affect the establishment of TSS. The criteria were determined through quantitative research using a survey questionnaire, which included the following: traffic-navigational, spatial-geometrical, manoeuvring, and meteo-oceanological criteria. The research involved experts with relevant experience, specifically deck officers responsible for maritime navigation, where TSS have been established, which ensures the quality and credibility of the research results.

Based on the research results, a machine learning model was developed and proposed to improve and speed up the decision-making process while offering a higher level of objectivity. To assess the effectiveness of the model, validation was conducted using real-world waterway scenarios, and the validation results indicate a high level of accuracy.

The proposed decision-making process offers an enhancement in the process of establishing TSS and can be used as an additional tool and mechanism for improving the existing procedure for establishing TSS, primarily based on using IMO guidelines.

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Validation of Questionnaire and Passenger Perceptions on QoS of Access Trip and Port: A Case Study in Dalian

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Keywords: quality of service; transit hub; user perception; survey; passenger maritime transportation

The Quality of Service (QoS) of passenger maritime transportation has received increasing attention in last two decades. Among them, research on the QoS of passenger port mainly focused on exploring the role of cruise passengers' satisfaction with the port in their behavioral intentions, especially the factors influencing their revisit or recommendation of destinations (Sanz-Blas, Carvajal-Trujillo and Buzova, 2017; Mikuličić et al., 2024; Montesdeoca and Tovar, 2024; Baños-Pino and Tovar, 2025). However, existing studies have limitations, with inconsistent findings on key variables such as the passenger port safety and insufficient consideration of the impact of emerging technologies such as Information and Communication Technology (ICT) on access trips before arriving at the port. To the authors' knowledge, there are no published and validated questionnaires on QoS of access trip and port yet.

To this end, extending the study in (Guirao, García-Pastor and López-Lambas, 2016), this paper aims to develop and validate a robust questionnaire and estimate the key factors affecting the QoS of access trip and port. Firstly, for a case study in Dalian, the research team developed an original questionnaire to consider not only conventional attributes, such as transportation accessibility, clarity of signage and information, facilities, terminal environment and perceived safety, but also new service system perception and passenger willingness, such as digital service experience based on ICT systems, overall satisfaction, willingness to revisit and to recommend. Then, an on-site survey was conducted in the Dalian Bay Shipping Center of Liaoyu Group in Dalian, China, between December 29th 2025 and January 4th 2026. Finally, a total of 489 valid surveys were collected. To validate the questionnaire, the Exploratory Factor Analysis (EFA) is employed to assess the factor structure of latent variables and validate their construct validity. The Kaiser-Meyer-Olkin (KMO) sampling adequacy index and Bartlett's sphericity test confirm the data's suitability for EFA. All latent variables demonstrate excellent Cronbach's alpha coefficients ranging from 0.982 to 0.995, as shown in Table 1 in Appendix A. The key factors of QoS of access trip and port are identified as well.

To summary, this study successfully developed and validated a questionnaire specifically designed to assess the QoS of access trip and port. This validated questionnaire provides a solid foundation for subsequent analysis. This approach can be applied in any other port or transit hub. The ongoing work is to explore the complex causal relationships between the identified factors of QoS and overall passenger satisfaction, loyalty, and recommendation behavior. Future research will focus on how port experiences impact overall travel experience.

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Table 1. Reliability and validity analyses.

Latent Variable	Number of items	Cronbach's Alpha	KMO	Significance	Convergent Validity
B1	5	0.992	0.747	P<0.001	One component extracted, explaining 96.95% of variance
B2	3	0.991	0.795	P<0.001	One component extracted, explaining 98.245% of variance
B3	5	0.990	0.884	P<0.001	One component extracted, explaining 96.037% of variance
B4	4	0.995	0.886	P<0.001	One component extracted, explaining 98.665% of variance
B6	2	0.988	0.600	P<0.001	One component extracted, explaining 98.831% of variance
B7	3	0.982	0.733	P<0.001	One component extracted, explaining 96.836% of variance

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Modernizing Maritime Education for Career-Ready Global Maritime Professionals: Bridging Curriculum, Industry, and Digital Transformation

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Keywords: maritime education; digitalization; knowledge management; career readiness; case studies; blue economy; USA

The global maritime sector is undergoing accelerated transformation driven by digitalization, decarbonization, evolving regulatory frameworks, and shifting workforce expectations. Despite these changes, maritime education and training (MET) systems in many regions continue to rely on traditional pedagogical models that inadequately prepare graduates for contemporary industry demands. This growing misalignment has intensified concerns regarding graduate career readiness, particularly in relation to applied competencies, digital literacy, sustainability awareness, and professional adaptability.

This paper examines the urgency of modernizing maritime education to produce career-ready global maritime professionals capable of operating in increasingly complex, technology-enabled, and sustainability-driven maritime environments. Drawing on selected case studies from higher education maritime programs, curriculum mapping exercises, and industry-informed competency frameworks, including alignment with the International Association of Maritime Universities' Global Maritime Professional Body of Knowledge (GMP-BoK), the study identifies structural gaps between existing MET curricula and evolving labor market requirements with focus in the maritime education programs in the USA.

Beyond curriculum reform and skills alignment, the paper argues that meaningful modernization of MET requires a knowledge management–oriented framework. The maritime sector is inherently knowledge-intensive, relying on the integration of tacit operational expertise, regulatory knowledge, technological know-how, and experiential learning across institutions and professional communities. However, much of this knowledge remains fragmented and weakly transferred between academia and industry. Embedding knowledge management principles within MET supports the systematic capture, organization, and dissemination of maritime knowledge, enhancing curriculum coherence, institutional learning, and workforce continuity.

The paper concludes by proposing practical strategies for MET institutions, educators, and policymakers to accelerate curriculum modernization through human-centred, digitally enabled, and knowledge-driven approaches. These strategies aim to strengthen career readiness pathways and contribute to the development of safe, green, and globally competent maritime professionals both on board of ships and on the business side of maritime operations.

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Exploring the Use of Artificial Intelligence to Evaluate Constructive Alignment

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Keywords: artificial intelligence; constructive alignment; qualitative analysis; IMO Model Course; action verb taxonomy

Constructive alignment (Biggs, 2003) emphasizes coherence among learning outcomes, instructional strategies, activities, and assessments to enhance student learning. While it has intuitive appeal, empirical evidence supports its effectiveness over traditional methods (e.g., Hamdoun, 2023; Zhang et al., 2022). Traditionally used to design courses, constructive alignment can also evaluate existing courses to identify misalignment. This study explores using artificial intelligence (AI), specifically ChatGPT, to objectively evaluate alignment in IMO model courses.

Research shows significant misalignment between learning outcomes and course aims in IMO model courses (Szwed et al., 2024; Szwed & Manuel, 2022; Szwed, Hanzu-Pazara, & Manuel, 2021). Past studies manually coded learning outcomes, a time-consuming process. Leveraging the IMO action verb taxonomy (IMO, 2022), ChatGPT automates verb extraction and classification into cognitive, affective, or psychomotor domains, comparing alignment between objectives, outcomes, and instructional modes.

A pilot study on five IMO model courses (i.e., MCs 1.20, 1.21, 1.37, 2.06, 2.07) showed ChatGPT achieved 93.6% accuracy compared to manual coding and reduced processing time by 82%. Results were easily auditable and improved with refined prompting, highlighting AI's potential for qualitative research. While effective in identifying domain-level alignment, module-level alignment involving nuanced interpretations (Anderson et al., 2001) may still require human-AI collaboration, consistent with findings from other studies (Ejjami, 2025; Morgan, 2023).

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