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# Transport 2040 : Impact of Technology on Seafarers - The Future of Work

World Maritime University


WORLD MARITIME UNIVERSITY

TRANSPORT 2040

# IMPACT OF TECHNOLOGY ON SEAFARERS

## THE FUTURE OF WORK

INTERNATIONAL TRANSPORT WORKERS' FEDERATION

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# IMPACT OF TECHNOLOGY ON SEAFARERS

## THE FUTURE OF WORK

"Digitalization and automation can be counted amongst the technologies that will help us on the voyage towards cleaner, greener and more efficient shipping but this does not mean that we ignore the human element. On the contrary, we must ensure that seafarers' welfare is properly taken into account, just as we need to ensure that current and future seafarers are adequately trained to handle shifting technologies while continuing to promote diversity and gender parity in maritime.

**Kitack Lim, Secretary-General, International Maritime Organization (IMO)**

"Seafarers provide a vital service to societies and play a crucial role in the functioning of global supply chains. In order to promote the recruitment and retention of seafarers, it is essential to secure full respect of their rights as enshrined in the ILO Maritime Labour Convention and help them get ready to cope with current and future technological developments. I therefore welcome the work conducted by the WMU under the project Transport 2040, with the support of the ITF.

**Gilbert F. Houngbo, Director General, International Labour Organization (ILO)**

*Quotes used with permission by the authors.*

> "From the lab to the boardroom to the messroom: worker's voices must be heard at every level. Once deployed, workers must be properly trained on how to safely use all new tools they're expected to harness. They must be fairly compensated, with paid familiarization time and where their skills are upgraded: so should their pay.

**Stephen Cotton, General Secretary, International Transport Workers' Federation (ITF)**

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# FOREWORD

Stephen Cotton
General Secretary
International Transport Workers' Federation

I welcome the publication of the next phase of WMU's important research on new technology and the future of maritime transport.

This report takes the WMU's renowned maritime expertise and applies to it the latest emerging technological and social trends – some of which are already shaping the world of work for maritime workers and their communities.

From the mess room to the boardroom, from unions to employers, from training providers to regulators: there is something for everyone in this report.

Its insights and findings should be of wide interest. Its recommendations, I am sure, will spark debate – and that is a very healthy thing for an industry so critical to global prosperity and connectedness.

There are some aspects of the report I wish to highlight at the outset.

Firstly, this report confirms what we in the trade union movement have been arguing for decades: that humans are not going anywhere when it comes to this sector. Whatever technologies are deployed from among those currently available, seafarers and other maritime workers will continue to be critical. Yes, new technologies will mean shipping will require different kinds of skills among seafarers, but seafarers will still be needed, nonetheless, for the overwhelming majority of vessels.

Smart ships, remote operations, autonomous vessels, and the widespread uptake of new and alternative propulsion sources have the potential to significantly transform our sector. But the independent researchers are plain in this report that these are long-term processes. By their nature, we cannot predict how things will look exactly in the end.

How we overcome that level of uncertainty and avoid technological dead-ends, major and minor, is by listening to each other. The report is strong in arguing that worker input early in the development and deployment of new technology can pay strong dividends for a safer, more engaged and sufficiently skilled workforce into the future. 'Nothing about us without us', is the maxim here, with authors highlighting the importance of social dialogue in successful technology use.

Without coordination, there is a risk that technology sprints too far ahead of what training providers can teach on how to use these tools safely. There is a risk that it leaps over regulators before they have a chance to know the real impacts on crew in the long run.

One example provided within this report's many valuable case studies, is of ferry workers who are expected to know how to safely charge and discharge a new battery system fitted on board their vessel. However, they find their training institution unable to keep up with the technological advances and its faculty unable to offer training courses on the new equipment's safe use. Furthermore, the workers felt under such pressure to make sailing schedules that they didn't have enough time to familiarize themselves with the new equipment.

We are well advised to learn from examples such as this.

Seafarers must be adequately trained to safely use all new tools they are expected to harness. This must be backed up by paid familiarization time, with seafarers relieved of their normal duties and permitted to focus on the learning at hand. We urge a 'safety-first' approach, where risk does exist.

Finally, this report confirms that education is critical. The seafarers of the future are going to need new skills, backed up by international competency and training frameworks. Our existing systems require reform and modernization. We believe that the social partners, including seafarers' unions, must all play an equal role in defining, building, and supporting a properly funded, modern and globally integrated training and skills education system.

To train the 800,000 seafarers needed to operate the ships of the future by the mid-2030s (and see off the worst impacts of the climate crisis) means this global education overhaul is absolutely urgent.

ITF has been pleased to have supported this important initiative. I would like to offer our sincere congratulations to Professor Aykut I. Ölçer, Professor Momoko Kitada, Associate Professor Fabio Ballini, and Assistant Professor Khanssa Lagdami, along with the researchers, assistants and administrators who have been critical to delivering Phase 2 of our research partnership with WMU on transport and new technology. I also wish to thank Brian Orrell for offering his time and valuable expertise to the WMU team when called upon.

This research is a credit to the leadership of WMU President Dr Cleopatra Doumbia-Henry, who has been a driving force behind its realization. It provides a strong foundation for incoming President Professor Max Mejia to rightly claim WMU remains at the helm of leading maritime research globally.

**About the ITF:** The International Transport Workers' Federation (ITF) is a global, democratic, affiliate-led movement of 740 transport workers' unions. It has been the global voice for maritime workers since its founding in 1896. ITF was granted consultative status at the International Maritime Organization (IMO) in 1961.

# PREFACE

Maritime transport drives world trade and is the backbone of the global economy. With more than 80% of the volume of international trade in goods carried by sea, shipping remains the only cost-effective way to transport this vast majority of international trade. Indeed, shipping is vital to sustainable global development and growth. New technologies and increased levels of digitalization and automation are continuously being introduced to the maritime field for reasons of safety, efficiency and the environment. However, the changes to society and employment brought about by rapid technological development should be thoroughly considered to ensure that seafarers are well-trained and motivated for the future. The second phase of the Transport 2040 flagship project undertaken by the World Maritime University (WMU) was launched in collaboration with the International Transport Workers' Federation (ITF) and various stakeholders to address the continued challenges of automation and digitalization that drive change in shipping and the maritime industry.

The previous report from the first phase of the project examined the changing nature of global transport, highlighting the need for nations to anticipate how emerging changes affect the nature of work. For workers to adapt and acquire the new skills required, education and re-training systems are of the essence. This current report for the second phase was designed specifically to study and focus on the role and direction of technologies and other global trends pertaining to maritime transport. The report provides facts that support an understanding of how the negative effects of technology on shipping can effectively be ameliorated and how the industry can prepare for evolutionary change brought about by digitalization and automation, a development that will affect seafarers in the short, medium and long-term.

I am very grateful for the continued support given by the UN institutions and the many other contributors in international organizations, government institutions, industry and academia. This study benefitted from their collaboration and made it possible to produce the results presented in this report. I truly appreciate the support of the ITF and its sustained confidence in WMU, which has allowed us to undertake the necessary research to prepare this report.

It is our hope that this report will make a significant contribution to the future of work at a time when the Maritime Safety Committee of the International Maritime Organization (IMO) decided at its meeting in April 2022 to commence work on the development of a new goal-based instrument regulating the operation of maritime autonomous surface ships (MASS) as well as the interaction and co-existence of MASS with conventional ships.

Action needs to be taken now for the maritime and allied industries to be ready and ensure the wellbeing of societies and communities worldwide by providing decent working conditions for the sector. Following the recommendations of this report, greater levels of collaboration between shipping, ports and logistic providers needs to be ensured to give renewed emphasis to education, training and capacity-building among stakeholders. The aim is for everyone, including seafarers, to enjoy the future benefits of automated, seamless seafaring.

As established by the IMO, WMU stands ready to play its part in the maritime and ocean industries towards providing research, education and capacity-building in support of the 2030 Agenda for Sustainable Development and the related Goals. The future of the sea is not yet set in stone. We must all work together to innovate and ensure that there is inclusive and sustainable employment in the maritime transport industry of tomorrow.

**Dr. Cleopatra Doumbia-Henry**
President
World Maritime University

# CONTENTS

# ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| ABC | Automated Boiler Control |
| AI | Artificial Intelligence |
| AR | Augmented Reality |
| ARPA | Automatic Radar Plotting Aids |
| ASAP | Aviation Safety Action Program |
| ATSB | Australian Transport Safety Bureau |
| BAU | Business As Usual |
| BDA | Big Data Analytics |
| BIMCO | Baltic and International Maritime Council |
| BMS | Boiler Management System |
| C188 | Work in Fishing Convention, 2007 |
| CAGR | Compound Annual Growth Rate |
| CBT | Computer Based Training |
| CCTV | Closed-circuit Television |
| CFR | United States Code of Federal Regulations |
| COLREGs | Convention on the International Regulations for Preventing Collisions at Sea, 1972 |
| CoP | Community of Practice |
| CS | Cloud Storage |
| CSTS | Cyber-Socio-Technical System |
| DPS | Dynamic Positioning Systems |
| DWEA | Danish Working Environment Authority |
| EARPs | Effective Emergency and Accident Response Action Plans |
| EASHW | European Agency for Safety and Health at Work |
| ECDIS | Electronic Chart Display And Information System |
| ECR | Engine and Control Room |
| EFTA | European Free Trade Association |
| EMC | Electromagnetic Compatibility |
| EMSA | European Maritime Safety Agency |
| ENC | Electronic Navigational (Nautical) Chart |
| ESCO | European Skills, Competences, Qualifications and Occupations |
| ESS | Energy Storage System |
| EU | European Union |

| | |
|---|---|
| EU | European Union |
| FAA | Federal Aviation Administration |
| FDR | Flight Data Recorders |
| GMDSS | Global Maritime Distress and Safety System |
| HA | Human Augmentaion |
| HCI | Human-Computer Interaction |
| HFO | Heavy Fuel Oil |
| HI | Human Intelligence |
| HR | Hurman Resources |
| HSBA | Hamburg School of Business Administration |
| HSEEQ | Health, Safety, Environment, Energy, and Quality |
| HTW | IMO Sub-Committee on Human element, Training and Watchkeeping |
| IBA | International Ergonomic Association |
| IBS | Integrated Bridge System |
| ICOH | International Commission on Occupational Health |
| ICS | International Chamber of Shipping |
| ICT | Information and Communication Technology |
| IGC Code | International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk |
| IGF Code | International Code of Safety for Ship Using Gases or Other Low-flashpoint Fuels |
| IIRSM | International Institute of Risk and Safety Management |
| IIT | Intelligent Information Technology |
| ILO | International Labour Organization |
| IMarEST | Institute of Marine Engineering, Science & Technology |
| IMO | International Maritime Organization |
| IoT | Internet of Things |
| ISM code | The International Management Code for the Safe Operations of Ships and for Pollution Prevention |
| ISMA | International Stress Management Association |
| ISO | International Standard Organization |
| ISPS | International Ship and Port Security |

| | |
|---|---|
| IT | Information Technology |
| ITECH | Innovative Technology Initiatives (ITECH) |
| ITF | International Transport Workers' Federation |
| KPIs | Key Performance Indicators |
| KUP | Knowledge, Understanding, and Proficiency |
| LIDAR | Light Detection and Ranging or Laser Imaging, Detection, and Ranging |
| LNG | Liquefied Natural Gas |
| LPG | Liquefied Petroleum Gas |
| MARPOL | International Convention for the Prevention of Pollution from Ships |
| MASS | Maritime Autonomous Surface Ships |
| MCI Code | Marine Casualities and Incidents Code |
| MET | Maritime Education and Training |
| METI | Maritime Education and Training Institution |
| MLC 2006 | Maritime Labour Convention 2006 |
| MSC | Maritime Safety Committee |
| MTCC | Maritime Technology Cooperation Center |
| NGO | Non-Governmental Organization |
| O*NET | Occupational Information Network |
| OBR | On-Boarding Recording |
| OSH | Occupational Safety and Health |
| QAR | Quick Access Recorder |
| R&D | Research and Development |
| RCCO | Remote Control Center Operator |
| RDR | Radio Direction Finder |

| | |
|---|---|
| RUL | Remaining Useful Life |
| SCC | Shore Control Centre |
| SOLAS | International Convention for the Safety of Life at Sea |
| SQA | Software Quality Assurance |
| SSS | Short Seal Shipping |
| STCW | International Standards of Training, Certification and Watchkeeping for Seafarers |
| STEEP | Social, Technological, Economic, Environmental and Political |
| STEM | Science, Technology, Engineering and Mathematics |
| STF | Skills Technology Foresight |
| TSIA | Transport Safety Investigation Act 2003 |
| TVET | Technical Vocational Education and Training |
| UAV | Unmanned Aerial Vehicle |
| UNCTAD | United Nations Conference on Trade and Development |
| UNSDGs | United Nations Sustainable Developement Goals |
| VC | Virtual Captain |
| VDR | Voyage Data Recorder |
| VHF | Very High Frequency |
| VR | Virtual Reality |
| WEF | World Economic Forum |
| WMU | World Maritime University |
| WOPS | Work Organization and Psychosocial Factors |

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World Maritime University (WMU) expresses its gratitude to the International Transport Workers' Federation (ITF) for financially supporting the research behind this report. This research would not have been possible without their commitment and encouragement to work on this topic. Jaqueline Smith and Brian Orrel are thanked explicitly for their support in completing this research project.

Under the overall guidance of Cleopatra Doumbia-Henry, President of World Maritime University, and the coordination of Professor Aykut I. Ölçer (Principle Investigator), WMU Director of Research and Professor Momoko Kitada (Co-Principle Investigator), the Transport 2040: the Future of Work (Phase II), Impact of Technology on Seafarers report was prepared by a team comprising of Aykut I. Ölçer, Momoko Kitada, Khanssa Lagdami, Fabio Ballini, Anas S. Alamoush, Peyman Ghaforian Masodzadeh and Joseph A. Reyes (chapter 1), Anas S. Alamoush and Aykut I. Ölçer (chapter 2), Momoko Kitada, Peyman Ghaforian Masodzadeh and Joseph A. Reyes (chapter 3), Khanssa Lagdami and Fabio Ballini (chapter 4), Khanssa Lagdami (chapter 5) and Momoko Kitada, Aykut I. Ölçer, Khanssa Lagdami, Fabio Ballini, Anas S. Alamoush and Peyman Ghaforian Masodzadeh (chapter 6).

This report has benefited from substantive contributions from Jens-Uwe Schröder-Hinrichs, Vice-President (Academic) of WMU; Michael Manuel, Academic Dean of WMU; Alessandro Schönborn, Assistant Professor as well as former colleagues, including Jane Tifuh, Guiditta Mikhail and Tiago Fonseca.

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This report is the result of almost three years of intensive research only made possible by many valuable contributions in the form of comments, recommendations and other inputs from a great many partners in different organizations, governments, industry and academia. To mention them all individually would be impossible. Their help and support is fully appreciated and acknowledged.

The language of this report was edited by Copenhagen Editors. Junko Flyman Kosaka designed the graphics in chapters 2-5, and the graphical layout as well as the graphics in chapter 1 were provided by Phoenix Design Aid A/S.

CHAPTER 1

# INTRODUCTION


1

**Authors:** Aykut I. Ölçer, Momoko Kitada, Khanssa Lagdami, Fabio Ballini, Anas S. Alamoush, Peyman Ghaforian Masodzadeh and Joseph A. Reyes

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# 1 INTRODUCTION

Through generous funding from the International Transport Workers' Federation (ITF), the World Maritime University (WMU) has conducted Phase II of the Transport 2040 flagship project, building on the previous Phase I of the project. Phase II offers a further in-depth exploration of a number of maritime issues related to future ship technologies, including automation, and seeks to qualify the probable impact on seafarers.

Recent discussions in the maritime sector have given rise to expectations that automated ships could become operative in the near future, which has prompted the International Maritime Organization (IMO) to initiate a number of activities. Digital smart technologies represent a new wave of opportunities and hold great potential not only for higher productivity and economic growth but also for the improvement of the working conditions and safety of seafarers. As addressed by the Phase I report of the Transport 2040 project, the many challenges associated with this new wave of technology need to be discussed so seafarers can equally benefit from this development. Among the most critical challenges addressed in this report is the acquisition by seafarers of the skills and competencies required by the fast-evolving new technology as well as the protection of their wellbeing in light of the impact these new technologies will have on their profession.

New technology poses new and higher requirements for advanced and more complex skills and competencies that are not only industry-specific and technology-related but also include interpersonal, managerial and creative skills.[1] Meeting these new industry requirements in a globally expanding shipping market will require continuous adaptation and lifelong learning by seafarers as tasks and jobs change. Indeed, the technological transformation will extend beyond routine cognitive and manual tasks to include analytical tasks, such as automated decision-making.[2] While the risk of task automation is high for certain occupational groups, this development is nevertheless unlikely to give rise to overall job loss. Automation technology will require several hurdles to be overcome by the maritime industry on a broad scale, which will arguably leave time for seafarers to reskill and upskill to new tasks and embrace emerging job opportunities.[3] Research is supportive of the expectation that new technology, as has historically been the case, may result in positive job creation and employment growth as the shipping industry expands.[4]

Indeed, the benefits of new digital technology are likely to be appropriated not only by capital owners but also by workers with the right skills. Upskilling and reskilling are therefore of paramount importance in the ongoing technological transition. Individuals with the right skills are more likely to be employed, be adaptable to disruptive change, and to sustain higher productivity levels.[5] Thus, for the maritime sector to be ready for the future, a robust approach should be pursued to map global trends on the horizon within key technologies. This mapping should include the accompanying policies, threats, and opportunities posed by the technological transition to address arising issues that include, but are not limited to, the training needs of seafarers to achieve the right skills, knowledge, and competencies. Since such macro-technological trends detailed in the research may manifest themselves differently in relation to form, time and location, the digital transition will not only affect the maritime workforce differently on a global basis in terms of skills training but also impact their Occupation Safety and Health (OSH) in localized ways.

Chapter 2 presents an assessment of current trends in automation and technology. New technology is key to the evolution of shipping and associated industries and will have a profound impact on seafarers in many ways. The chapter primarily addresses future shipping technologies intended for both conventional and Maritime Autonomous Surface Ships (MASS). The central research findings identified 10 main technologies and 26 sub-technologies as well as 10 global trends that could influence the maritime sector. Moreover, maritime stakeholders collectively determined a set of policies that could potentially decelerate/accelerate future trends and support future technology. The implications of the integration of such technologies have been considered for various stakeholders, including the corresponding threats and opportunities they pose for the maritime sector. Relevant results have been consolidated into a Technology Road Map that provides a full picture of the future of shipping. Although cutting-edge and future shipping technologies have been listed as stand-alone developments, they are also referenced in other chapters of the report dealing with interrelated maritime issues.

Future maritime competencies, skills and career opportunities are discussed in chapter 3, which focuses on the skills requirements of the future as identified through stakeholder workshops, surveys, and literature. The analysis encompasses inter-project synergies with respect to the consistency and validity of the results with reference to the findings of Phase I and other seminal studies as well as seafarer demographics. The results have been consolidated to provide a holistic picture of the changing work environment and values for seafarers, while setting out strategies and recommendations for necessary maritime education and training initiatives to prepare the workforce for the maritime job and career opportunities of the future. Chapter 3 particularly aims to identify the skill sets required that will enable seafarers to reap the benefits of technological advancement. By anticipating the development of skills requirements within a 2040 timeframe, chapter 3 investigates the reskilling and upskilling needs that will allow seafarers to work in a more automated, smarter and greener maritime industry.

The above-mentioned chapters 2 and 3 of this report cover the technical and skills aspects of automation and discuss what impact the technological transition will have on the maritime transport labour force in the years ahead, while setting out specific recommendations in support of the technological transition towards automation.

Chapters 2 and 3 are followed by chapter 4, which presents the Maritime Country Profiles. These profiles were originally designed for and included in Phase I but have been expanded in Phase II in terms of their analytical depth and geographical coverage. With the version of the Maritime Country Profiles in this report, five indicators have been used to assess the readiness of countries to adopt innovation and technology in the maritime sector. These indicators are 1) Technology and Innovation; 2) Labour Market and Human Capital; 3) Economics and Business; 4) Social Acceptance; 5) Regulation and Governance. By adding further data to the profiles, WMU has sought to provide more detailed insights for maritime stakeholders.

A total of 23 selected States from different continents are presented in chapter 4. In Africa: Nigeria, Ghana, Kenya, South Africa, and Egypt. In the Americas: Chile and USA. In East Asia and the Pacific: Philippines, Indonesia, India, Bangladesh, Viet Nam, China, Republic of Korea, Sri Lanka, Japan, Myanmar, Singapore, and Thailand. In Europe: UK, Germany, Sweden. In the Middle East, Iran (Islamic Republic of) was selected for analysis.

Overall, our analysis indicates clear challenges in the development and implementation of technological and innovation measures as well as a lack of appropriate business models in the maritime sector. Also evident is that most countries have not implemented a proper incentive mechanism to improve infrastructure and competitiveness. However, our assessment has observed a favourable trend in social acceptance and regulation governance for developing countries and positive trends in the labour market and human capital fields generally. Chapter 4 also highlights a promising gradual trend in reducing the gap between developed and developing countries in the maritime sector.

An added dimension to the Maritime Country Profiles are the Country Reports, which are the coverage of chapter 5. These reports break down the information offered in the Country Profiles, resulting in a more in-depth analysis as well as providing other useful local information. The Country Reports thereby not only include aggregated socio-economic studies and an analysis of macro-trends within automation and other technologies and, they also offer a series of wide-ranging insights based on an extensive literature review and the contributed views of different maritime stakeholders.

In brief, this report seeks to provide a way forward for discussions on the future of the seafarer profession. It shows how automation and digitization may prove beneficial to the progress of the sector provided that it is well managed and appropriately applied. It is the hope of the WMU team that the case studies included in this report will inspire a greater discussion on the OSH of seafarers and the protection of their labour rights as well as the policies and reforms that are needed to support the future wellbeing of the maritime workforce.

Our research has resulted in four Country Reports on selected themes related to the impact of new technologies on the OSH of seafarers, including:

1. AI, Big Data at sea: exploring the potential risk of surveillance of seafarers (Case of Australia)
2. Technostress at sea (Case of Denmark)
3. Batteries as an alternative power source for ship porpulsion: seafarers OSH considerations (Case of Sweden)
4. Shipboard internet use: an investigation into its influence on the OSH of seafarers (Case of Panama)

Insights for relevant stakeholders have furthermore been provided in the interest of preparing the industry for the pace of change and innovation to come. Also highlighted is the disruptive potential for low-skilled and medium-skilled workers as well as the broader societal implications of automation, not least the substantial gains in efficiency, safety and productivity promised by technological advancement. This transition also necessitates corresponding regulatory and legal action to allow the sector to adapt. Enacting adequate regulation to ensure the success of the technological transition will take the concerted effort of all stakeholders including State governments, the business sector, trade unions, seafarers, and regulatory bodies.

The following section of this introduction discusses the methodologies utilized to achieve the objectives of Phase II of the Transport 2040 project.

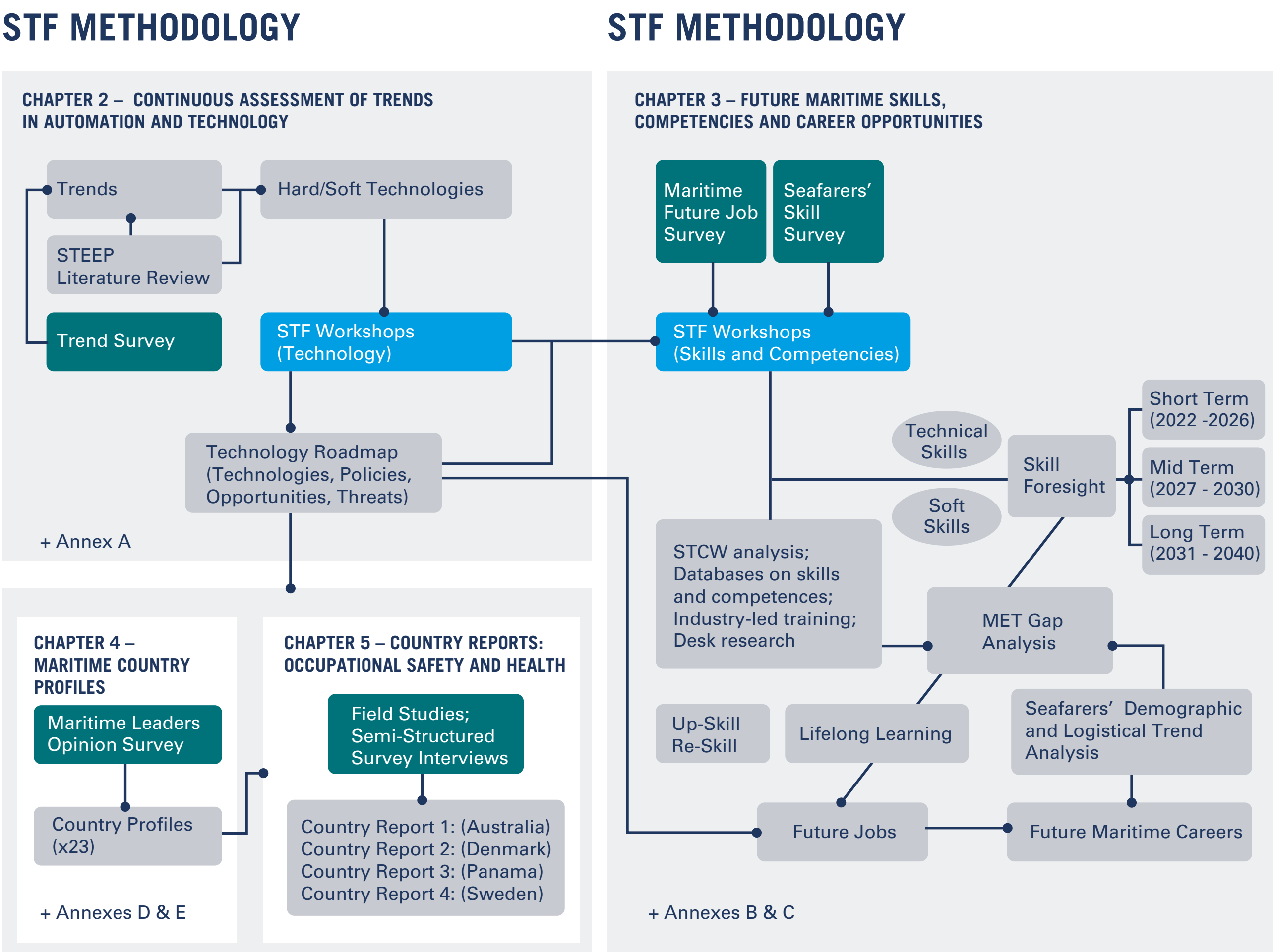
# 2 METHODOLOGY

## 2.1 SUMMARY OF THE METHODS

The analyses undertaken in support of the corresponding chapters of this report are based on the thematic expertise of the WMU team in addition to surveys among stakeholders, a further extensive review of the literature in the field, and consultations with international maritime experts and seafarers, which have been conducted to source additional background material and information as well as for validation. Information and primary data collected from surveys and workshops during Phase II of the Transport 2040 project were analysed utilizing qualitative and quantitative methods, focusing on technology-related issues and their impact on employment as well as any wider maritime labour market implications, including OSH. Validation and triangulation of the results were furthermore conducted for the study regarding data sources, data collection methods and analytical approaches.

The Skills Technology Foresight (STF) methodology[6] developed by the International Labour Organization (ILO) and SKOLKOVO was used to carry out the research for chapters 2 and 3. The STF methodology reflects the best international practices and foresight approaches to skills in the context of technological change (see Figure 1.1). We have adapted this methodology to the context of Phase II of the Transport 2040 project since the occupation-specific sector has a global rather than a local focus due to the global labour market of seafarers.[a]

FIGURE 1.1 The interrelations between the chapters and their methodologies




Notes: STF stands for Skills Technology Foresight. STEEP is the analysis of Social, Technological, Economic, Environmental and Political trends affecting the seafaring labour market.

[a] Following the latest discussions during the IMO MASS Working Group, we consider seafarers as a broader set of workers than the case is in the Maritime Labour Convention, 2006 as amended. This broader term may also include MASS remote operators or "e-farers".

## 2.2 CHAPTER 2: CONTINUOUS ASSESSMENT OF TRENDS IN AUTOMATION AND TECHNOLOGY

The aims of chapter 2 are firstly to provide an assessment of future shipping technologies (road mapping) and secondly to build a Technology Road Map that shows the anticipation of future technologies over time (short, medium, long terms). The Technology Road Map is aligned with the main ILO - SKOLKOVO STF methodology that is also consistently utilized as a key input for chapter 3. Two of the inputs from the STF methodology (technologies and trends) as well as one of its main outputs (the Technology Road Map) are derived from this chapter.

Based on the STF methodology, the first step was to identify global trends, particularly those that influence the maritime industry, since awareness of the trends helps stakeholders select the appropriate technologies that respond to these trends. Through a literature review, an initial horizon scanning subsequently resulted in a listing of 100 trends that were consolidated and aggregated into broader groups. Additionally, a survey questionnaire invited 112 experts within the global maritime transport industry to validate these trends affecting the sector by 2040. The aim was to identify the most critical trends. The result was an aggregation of the top-30 trends, which in turn were validated by the STF technology workshops.

The second step of the analysis was the identification of soft and hard technologies through a systematic literature review. The technologies and trends were used as input for a series of STF technological workshops. The validation was conducted in consultation with experts within the field as well as relevant stakeholders, including technologists, researchers, policymakers, shipping managers and owners, shipping associations and NGOs. Three workshops were organized to consult with industry and stakeholders to prioritize technologies over time (short, medium and long terms). Workshops were subsequently conducted. The first was held in December 2021 and the following two in the second and fourth week of March 2022 respectively and were attended by 50 maritime experts. The experts selected the top-10 trends, rated upcoming technologies in terms of probability and identified the policies that are required to accelerate technology integration as well as the opportunities and threats posed by the technology for all maritime stakeholders. The results were aggregated in a Technology Road Map as a final format that enables the visualization of the findings and includes empirical validation and rating of results through expert workshops. The Technology Road Map conveys to the maritime industry the potential of future technologies, including automation technologies used in MASS. The chapter also identified the underlying issues of these technologies, i.e. the drivers, motivations, barriers and gaps.

## 2.3 CHAPTER 3: FUTURE MARITIME SKILLS, COMPETENCIES AND CAREER OPPORTUNITIES

Identifying future skills (through the STF) is a demanding and complex task usually undertaken by governments due to its resource-intensive requirements. The supportive methodologies available include participatory methods, quantitative methods, and secondary data analysis in mixed methods.

The STF methodology relies on a series of participatory workshops in which a multidisciplinary team of experts foresee developments within technology and skills. Prior to the workshops, desk research was undertaken to gather adequate information that was as accurate as possible to guide the STF workshops. Additionally, the trends and technologies identified earlier in chapter 2 and the results of two surveys, namely a maritime future job survey and seafarer skills survey, were used to support the workshops. The objectives of the workshops were to identify and describe future work tasks and working conditions. The workshop sessions took the form of focus groups attended by identified experts within the field.[b]

In light of COVID-19, these three workshops took into account the impact of the pandemic on seafarers and the future of their jobs. In parallel with STF, desk research was undertaken to identify current work tasks and skills, training courses as well as current STCW gaps. This information was compared with the foresighted future work tasks and working conditions and a gap analysis was subsequently conducted comparing the required and available skills, knowledge and competencies in the industry.[c] The whole process in this chapter is illustrated in Figure 1.1.

[b] A focus group session is highly interactive as the participants interact among themselves rather than answering questions posed by the facilitator of the session. The facilitator ensures the various stages of the foresight session are attained but does not direct the group to a specific agenda.

[c] The European Qualification Framework (EQF, 2017) defines knowledge as a body of facts, principles, theories and practices related to a field of work; a skill as the ability to apply knowledge and use knowhow to complete tasks and solve problems; and a competence as a proven ability to use knowledge, skills and personal, social and/or methodological abilities. For example, the position as a Captain requires the competence to combine knowledge about COLREGs and skills related to the steering of vessels.

## 2.4 CHAPTERS 4 AND 5: MARITIME COUNTRY PROFILES AND COUNTRY REPORTS

The Maritime Country Profiles and Country Reports Phase II of this research intend to highlight local trends implemented at different times and levels within different localised socio-technical contexts worldwide. The Maritime Country Profiles Phase II intends to expand the geographical coverage of the Maritime Country Profiles beyond the 17 countries already assessed in Phase I to a broader set of 23 countries, thus supporting a more accurate assessment of the status of automation and other new technologies around the world. The data analysis is based on surveys among maritime professionals.

The Maritime Country Profiles offer an assessment of the current state of play of a number of countries in terms of maritime innovation, technology adoption and other related factors. The countries are ranked by their score. Their overall score is based on five equally weighted factors: 1) Technology and Innovation; 2) Labour Market and Human Capital; 3) Economics and Business; 4) Social Acceptance; 5) Regulation and Governance.

These factors set the foundations for the Country Reports that combine elements from the Maritime Country Profiles and specific technology and transformation reports with a specific interest topic related to the OSH of seafarers. The Country Reports are developed based on field studies on board ships as well as semi-structured interviews with seafarers and stakeholders selected on the basis of the topics of the Country Report (case study).

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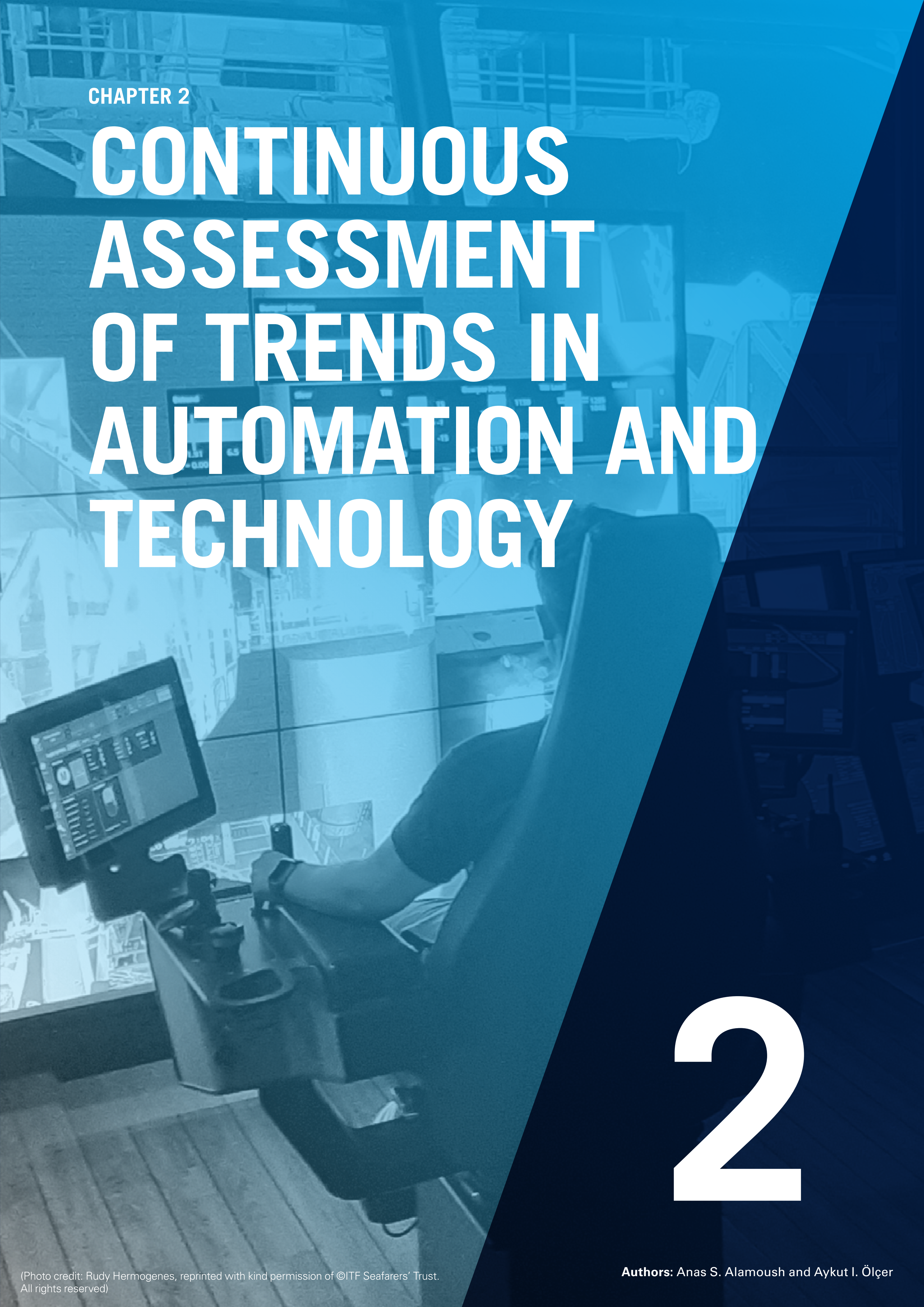

CHAPTER 2

# CONTINUOUS ASSESSMENT OF TRENDS IN AUTOMATION AND TECHNOLOGY

2

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**Authors:** Anas S. Alamoush and Aykut I. Ölçer

# SUMMARY

This chapter presents a Technology Road Map,[a] which is the result of a mapping of automation and other future technologies of the maritime transport sector. The identification of technologies in this assessment was based on a thorough desk research that included an unbiased Systematic Literature Review (SLR) as well as a review of technical and industrial reports. Further validation was conducted by maritime experts through a series of workshops that aimed to build a time horizon for the different road-mapped technologies. The review covers Maritime Autonomous Surface Ships (MASS), including all levels of autonomous technology compatible with MASS or otherwise relevant to future conventional shipping as such. Furthermore, future trends were identified that may influence the maritime transport sector and thus seafarers. In addition to the reviewed technology, potential policy requirements were studied along with opportunities and threats posed by the technology relevant to various maritime stakeholders. The results of this bird's eye review is a Technology Road Map that covers short-term (2022-2026), medium-term (2027-2030) and long-term (2031-2040) horizons.

The architecture of STCW functions related to MASS systems and subsystems was furthermore mapped, including the following aspects: navigation technologies (autonomous), remote and automated operation of machinery (engines, motors and generators), automated and remote maintenance and repair, cargo handling and stowage, operational control technologies, and hull technologies.

MASS automation technologies were additionally re-clustered into: Artificial Intelligence (AI); situational awareness and monitoring sensors; advanced actuators; Shore Control Centres (SCC); and advanced designs and system integrators. Notably, some technologies identified as being relevant to MASS are additionally relevant to conventional shipping, such as communication, connectivity and digitalization. Such overlapping technologies are separately included in further nine main technological categories that cover all technological innovations for future shipping, i.e. communication technologies, cybersecurity, digitalization technologies, robotics and drones, advanced materials, advanced sensors, low and zero-emission technologies, Human-Computer Interaction (HCI), and human augmentation. All these technologies are presented in brief in the annex A (Table A1: List of future shipping technologies).

# 1 INTRODUCTION

This chapter presents an analysis of future trends within automation and other future shipping technologies. The analysis is presented in the form of a Technology Road Map that serves as a forecasting tool for policymakers to support their decision-making for the future. Indeed, enhanced knowledge about the short, medium and long-term development of technologies benefits policy and decision-makers by strengthening their capacity to identify risks and opportunities and thus envision the right policy developments and take the right investment decisions at the appropriate time.

[a] Road Map is different from Road Mapping. Road Mapping is the whole process of the review (SLR), whereas the Road Map is that final and broad picture of the future, which consists of technologies integration over time horizon

# 2 TEN TRENDS INFLUENCING COMMERCIAL SHIPPING

A trend is a general development or change in a situation or in the way that people are behaving, i.e. what may lie beyond the horizon as an array of possible futures. Identifying global trends within the maritime industry is critically important since such knowledge helps stakeholders select trend-relevant technologies. When identifying these trends, the first step was to gather and review adequate and relevant information. The screening of relevant grey and academic publications resulted in the identification of 110 trends, which were subsequently grouped into a STEEP approach, i.e. Societal, Technological, Economical, Environmental, Political. Next, without loss of generality, the trends were clustered into a working list of 58 trends, which were further evaluated in an online survey that included feedback from 112 specially selected experts. This survey narrowed the scope of trends to 30 relevant topics (see the trend list in Table A2 in the annex A). Three different workshops were subsequently held attended by 50 different global maritime experts and stakeholders. Here, the top-30 trends were narrowed down to the 10 leading trends most likely to influence the maritime industry in the short, medium, and long-term.

## THE TOP-10 TRENDS:

### 2.1 TREND ONE: ECONOMIC/ INCREASING E-COMMERCE AND DIGITAL CONSUMPTION

Consumption patterns are constantly changing. The need for intermediaries between producers and consumers is narrowing due to e-marketing, e-stores and e-platforms. As a consequence, shopping behaviours are shifting towards specialized channels that employ sophisticated targeting strategies, such as demographic categorizations using search engine optimization, social media marketing and media marketing where the statistics provided by these channels are used to promote and understand consumer culture.[1]

### 2.2 TREND TWO: ECONOMIC/ EXPANDING ROLE OF THE BLUE ECONOMY

The United Nations Blue Economy Concept Paper (2021) defines the Blue Economy as an initiative developed by Small Island Developing States (SIDS). This concept paper is potentially also of interest to coastal states and countries with concerns regarding waters beyond national jurisdiction as well as nations that see the oceans as development spaces that require a planning process for conservation, sustainability, bioprospecting, energy production and maritime transport. Under the Blue Economy scheme, the main activities are fisheries; aquaculture; tourism (in coastal and marine areas); extractive offshore industries within and beyond national jurisdictions; freshwater generation; renewable energy offshore production; maritime transport, port, shipbuilding, shipping and other related services; and water disposal and other supportive services in the maritime field.[2] Climate change and renewable energies are important topics of this trend.

### 2.3 TREND THREE: ECONOMIC/ RISE OF NEW BUSINESS MODELS AND ECOSYSTEMS DRIVEN BY TECHNOLOGY

The digital transformation of business models will no doubt further change how the organizations interact and hence the business ecosystem as a whole. The technologies currently driving change include blockchain, AI-applications, the Internet of Things (IoT), digital supply chains and logistics management. These developments require businesses to deal with cybersecurity, 6G technologies and smart contracts.

### 2.4 TREND FOUR: ENVIRONMENTAL/ EXPANDING GREEN ECONOMY

Green economy trends seek to mitigate climate change and reduce the world's negative externalities by restructuring the world economy in support of such goals. Negative externalities include carbon emissions, pollution, wildlife endangerment, global warming, ocean coral bleaching, and intense tropical cyclone activities. Within this context, in 2011, during the

United Nations Climate Change Conference in South Africa, 194 participating countries agreed to set up a fund to help reduce greenhouse gas emissions after 2020. The path to establishing a low-carbon economy requires the reduction of fossil fuel-based energy consumption, implementing renewable energy sources, and where possible, embracing a zero-waste approach in production processes.[3]

## 2.5 TREND FIVE: POLITICAL/ INCREASED GEOPOLITICAL VOLATILITY

International developments within the economic and diplomatic fields are influenced by a number of factors, including: uncertainties; rivalries; shocks, such as political tensions; macroeconomic shocks; terrorist attacks; access to energy and natural resources; and global pandemics. Changes in political administration and diplomatic issues between nations may affect the prices of goods, oil and gas, commodities, and even the stability of different regions, which can cause disruption to the international system.[4] Forecasting geopolitical events and their risks is inherently impossible, which is why risk-hedging and management protocols are widely adopted to prepare countries for fluctuations in the financial and trade markets. Recent global geopolitical disruptions have included Brexit, the COVID-19 pandemic and the Ukraine/ Russia crisis. Future disruptions may emerge owing to factors such as the price of petroleum and commodities, new pandemics, the use of cryptocurrencies, wars and terror attacks.

## 2.6 TREND SIX: POLITICAL/ INCREASING ROLE OF TECHNOLOGY REGULATION AND GOVERNANCE

The advancement of technology has created the need for proper governance to ensure more efficient processes and to deal with ensuing challenges. Defining standards for technology within the governance area is a complex process where topics such as diplomacy and science at local, national, transnational and global levels must be codified on a regulatory framework. This undertaking befalls governments and international organizations.[5] Due to the increased use of Information Communication Technology (ICT) within business as well as in the private lives of citizens, new regulations covering the use of this technology by all stakeholders involved are being developed and enacted by governments, including the application of risk management tools and the common ground rule. However, the trend towards further regulation of data protection and information-sharing on the Internet poses the risk of evolving into methods to control political dissidence and curb civil freedoms.[6]

## 2.7 TREND SEVEN: SOCIAL/ WIDENING ECONOMIC AND SKILLS INEQUALITIES

The socioeconomic differences between the members of a society are generally rooted in their skills level in relation to labour market needs and requirements. A general lack of skills training in a society may contribute to the intransigence of a given socioeconomic system.[7] This dynamic is not set to change in the near future where highly-skilled individuals will continue to earn higher wages than individuals with medium and low-skilled profiles, who will also continue to struggle to gain sufficient education to change their economic standing. Moreover, in a world where digital skills are ever-more important and where the lack of such skills will become a significant determinant in the widening of inequality, adequate access to the Internet will be instrumental to change. Countries that invest in technology for educational purposes are therefore more likely to reduce both economic and skill inequalities. The same is true of investment in e-learning platforms and in children's lifelong learning and in family stability. The trend towards supporting skills-learning and personal opportunity through digitalization is especially important within maritime transport where addressing inequality will require the reskilling of seafarers and other employees as well as investment in assistive technologies, such as broadband Internet.

## 2.8 TREND EIGHT: TECHNOLOGY/ INCREASING CONCERNS ABOUT AND SOLUTIONS FOR CYBERSECURITY AND DIGITAL TRANSPARENCY

Cybersecurity has become a growing concern for industries due to the increase of digitalization (IoT, blockchain, Cloud, ICT) and the associated cyber threats. Threats to cybersecurity may affect the stability, safety, and security of nations, which is why individual states and stakeholders are developing preventative strategies within different industry spheres, including air freight and maritime transport, which are not only susceptible to being attacked physically but also experience cyberattacks. Countries have therefore increased their awareness of cybersecurity not only in relation to their national security and defence policies but also in relation to technology, including global navigation satellites systems, automatic identification systems, satellite communications, IoT, digital and smart contracts, etc.[8] In support of this trend, the International Maritime Organization (IMO) adopted Resolution MSC.428/98 regarding Maritime Cyber Risk Management in Safety Management Systems, which requires shipowners to address cyber risks and cybersecurity attacks in the design and deployment of Safety Management Systems (SMS). In January 2021, it became mandatory to deploy SMS and to consider cyber risks as potential threats.[8]

## 2.9 TREND NINE: TECHNOLOGY/ INCREASED USE OF SMART SHIPS

Motivated by smart shifts within other interconnected industries and sectors, the use of smart and digital ships is currently expanding and will grow even further with the wider utilization of technologies such as AI, digitalization, machine learning and mature semantic and cognitive technologies. The future ship will be smarter; data-driven; greener due to flexible powering options; and offer full onboard WiFi and digital connections through global satellites and mobile communications.[9] Such ships will also integrate with the wider global fleet as well as shore-side supply chains to enable Big Data Analytics (BDA), thereby providing information on a wide range of issues, including operations and maintenance costs, the reliability of the vessel, logistics, life cycle designs, energy consumption, emissions levels, and cargo monitoring.[10] In addition, smart ships will offer gains within efficiency and ease of transport, which is why stakeholders are likely invest more in such ships.

## 2.10 TREND TEN: TECHNOLOGY/ RISING IMPORTANCE OF AUTONOMOUS SHIPS

Automation is set to gain momentum, driven by sophisticated sensors, software, machine and deep learning, and global communication links. Ships will become situationally aware, self-governing and capable of doing tasks with limited external intervention (i.e. become autonomous). Currently, a wide variety of global projects have been established to build MASS prototypes. Countries such as Norway, Finland, Korea, Japan, and China are investing in autonomous ship projects due to the importance of their shipyard industries, which ultimately will increase their influence in the maritime field.[11] Technology is being advanced by MASS projects, particularly within AI-enabled autonomous navigation and remote control. Developing a fully autonomous oceangoing vessel will take time. However, stakeholders may eventually consider investing in this full-scale transition due to the anticipated economic, environmental and operational benefits the technologies promise, although there are several inhibitors, such as safety and technical issues and social awareness of the potential negative consequences to employment. Overall, it is anticipated that onboard and onshore seafarers (i.e. e-farers or operators) would need to be reskilled and upskilled to adapt to MASS.

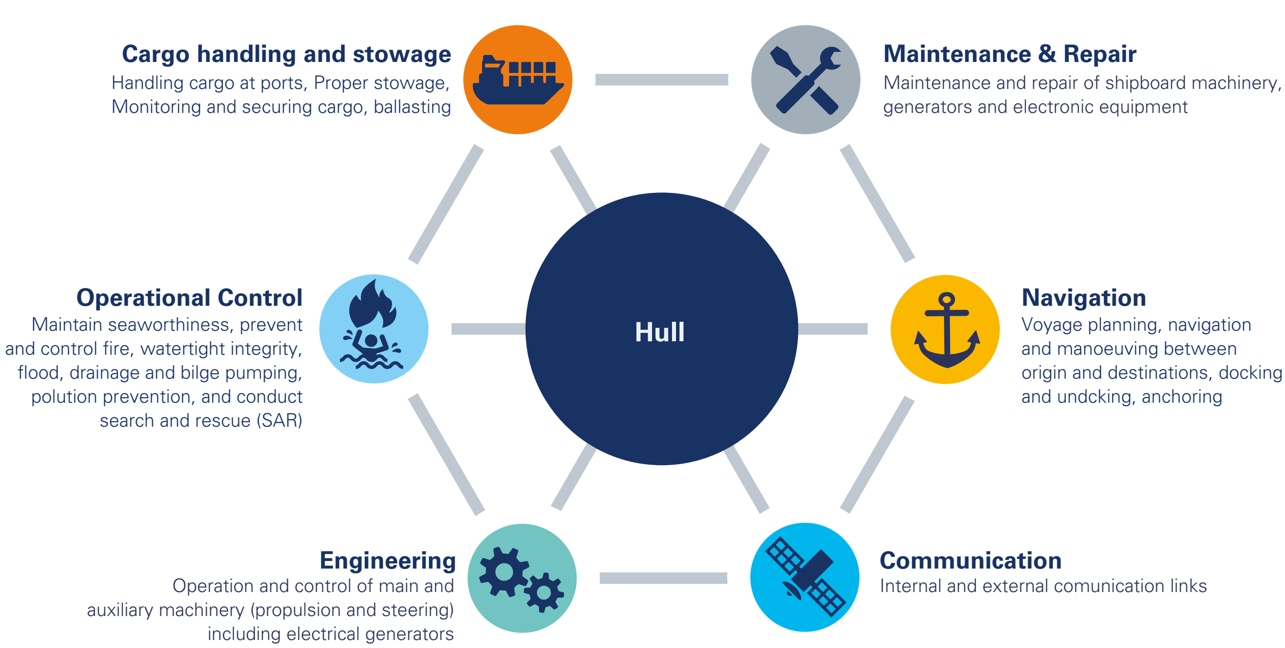
# 3 TRANSFORMATIONAL FUTURE TECHNOLOGIES THAT ENABLE SMART, DIGITAL AND AUTOMATED SHIPS

Technology advancement has historically fuelled global population growth – from 1.6 billion to 6 billion in the twentieth century alone – while also improving health, living standards, and the overall quality of life. The emphasis in the twenty-first century is on sustainability and the potential of technological innovation to meet innovation demands as well as the health of the planet.[12] Shipping technology is no exception. The industry is currently dealing with various issues, including safety, the environmental footprint, transparency, and connectivity. Future technologies are therefore expected to enhance safety and improve energy and operational efficiency, etc. Highlighted in the following is the wide scope of technologies that are expected to revolutionize shipping in the short, medium, and long term.

## 3.1 AUTOMATION TECHNOLOGIES

The advances in automation technologies, particularly MASS, are motivated by social, environmental and economic drivers. From a social perspective, MASS is expected to offer a solution to the anticipated shortage of seafarers, improve the quality and safety of seafaring jobs, and facilitate gender parity. Environmentally, MASS is expected to improve energy efficiency and reduce water and air pollution through digital and smart technologies. From an economic perspective, it is argued that less space required for crew cabins would save capital and operational costs, while also creating more space for cargo. Additionally, it is expected that MASS would improve supply chain optimization and resilience to provide smart and efficient operations. Despite the potential advantages of MASS and the drivers of the technology, there are evident barriers to the adoption of MASS. Concerns about the safety of MASS technology and other security risks in addition to the economic implications are seen as clear inhibitors. The perceptions of seafarers and shipowners on removing seafarers from ships, legal and regulatory barriers, technical and commercial issues, and skills and competency limitations are other barriers that may further inhibit a broader adoption of MASS.

FIGURE 2.1 Dimensions of MASS technologies



The dimensions of MASS technologies (Figure 2.1) is derived from STCW specifications. The technologies are thus defined by the requirements of various systems and subsystems. Figure 2.1 illustrates six technology clusters: navigation technologies (autonomous); remote and automated operation of machinery (engines and generators); automated and remote maintenance and repair; cargo handling and stowage; operational control technologies; and hull technologies. It is worth noting that communications are relevant for both MASS and conventional shipping. These technologies are therefore treated separately from the automation technologies. In turn, automation technologies were clustered into five groups that overlap all the systems and subsystems mentioned earlier. These clusters are: AI algorithms for situational awareness, monitoring sensors, advanced actuators, SCC, advanced design and system integrators (see Table A1 in the annex A: List of future shipping technologies).

Autonomous navigation is the ability of a ship to navigate on its own, avoid collision and maintain a safe navigational course to reach its destination. This can be achieved by training or programming the ship, including the utilization of stored data about the ship's behaviour in various sailing environments. MASS autonomous navigation is dependent on onboard computers with software to support decision-making and sensors that enable situational awareness and collision avoidance. When operating in remote control mode, SCCs may also help avoid collision and thus support autonomous navigation, which in fully autonomous ships relies on a Level 4 Autonomy technology and AI machine and deep learning.[13] Figure 2.2 lists the main sub-technologies required with MASS navigation: the Virtual Captain (VC); situational awareness technologies; collision avoidance technologies; motion control and path-following technology; and dynamic positioning technology.

The remote and automated operation of ship machinery includes the main and auxiliary engines/motors as well as electrical generators that feed the electrical, control and navigational systems and electronic equipment. According to the EU MUNIN project,[14] achieving sufficient technical reliability in an uncrewed engine room requires the following technology: 1) condition-monitoring devices that facilitate the prevention of technical failures, 2) inbuilt technical resilience systems that may limit the consequences of technical failures, 3) backup systems, and 4) fail-to-safe functions incorporated into critical safety systems as a last resort.[14–16] Importantly, actuators and the Condition/vehicle health monitoring system, which depends on monitoring sensors, are the key technologies required with uncrewed and autonomous machinery. The monitoring sensors collect diagnostic and prognostic data (based on algorithms) and use statistical information to determine the Remaining Useful Life (RUL) of components to thus facilitate timely and proactive maintenance (see Figure 2.3).[10,17]

FIGURE 2.2 Autonomous navigation system sub-technologies

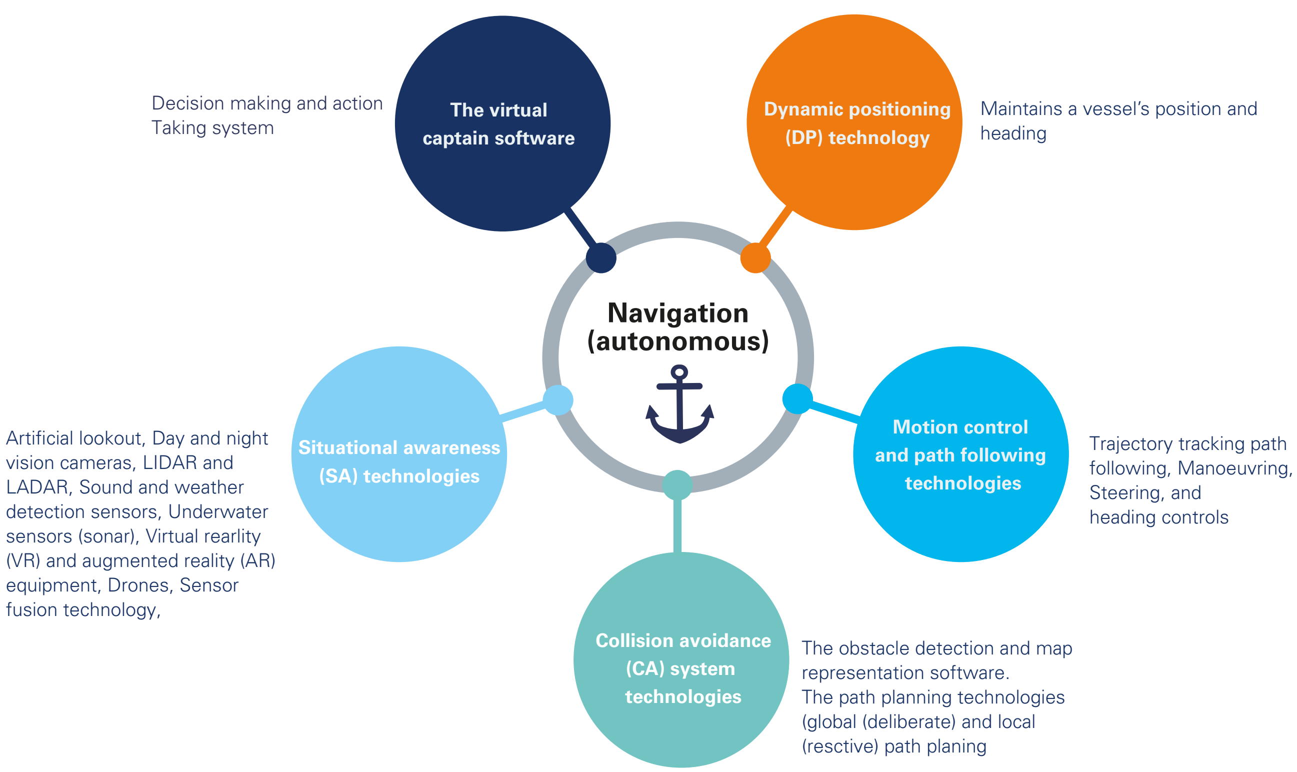
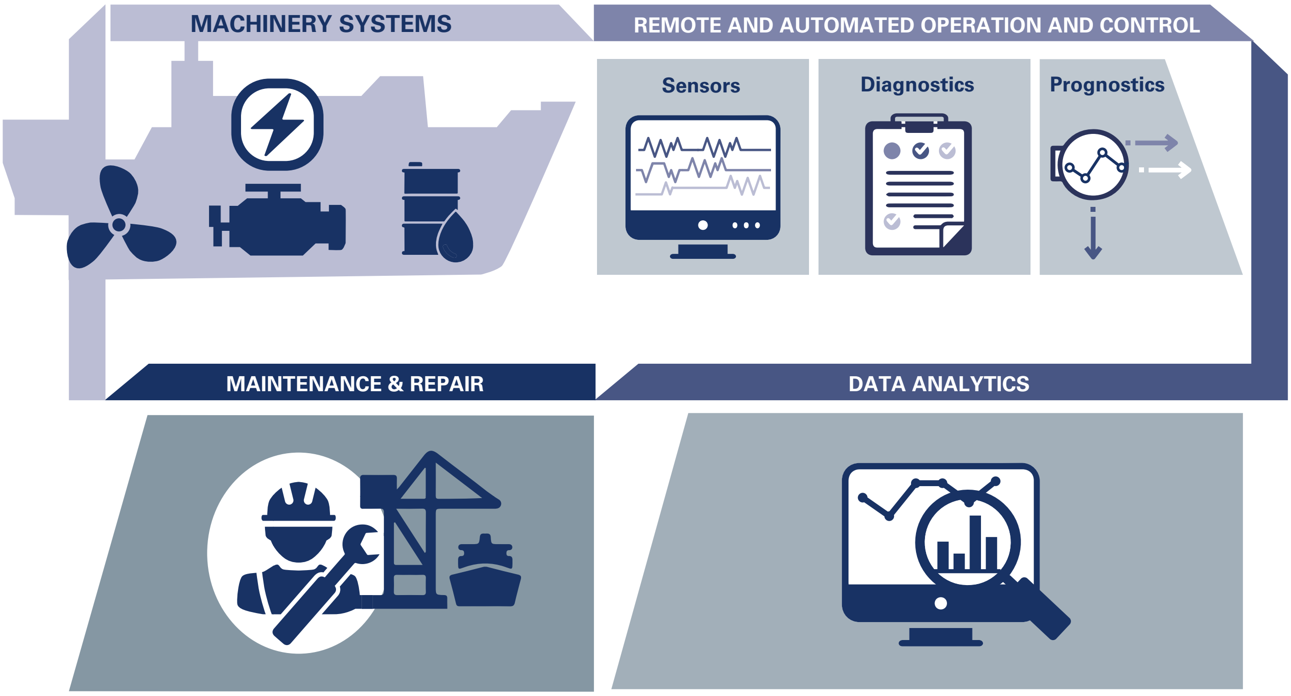


FIGURE 2.3 Ship condition-monitoring process




Automated and remote maintenance and repair of the engineering system encompasses engines, steering, generators, and electric and electronic equipment. With future MASS, systems providers and manufacturers as well as SCCs will be able to conduct maintenance and repair activities remotely. This will be facilitated by Augmented Reality (AR), robotics and drones. With MASS, most functions currently carried out by shipboard crews are expected to be delegated to the Artificial Chief Engineer (ACF), which is an AI-assisted software either available on board or on shore at the SCC. With advanced automation, modular designs are needed to facilitate the changing of faulty subsystems with backup systems.[10,18] Automated maintenance and repair will rely on robotics and drones, self-regulating equipment, fault tolerance machinery and materials that are smart, durable and capable of self-cleaning, sensing and healing.

With cargo handling and stowage, the role of MASS and remote control in quay-side cargo operations and transport will be limited compared to current conventional shipping. Automation technologies and monitoring sensors will be utilized, while the operations themselves will be tele-operated by SCC personnel. Additional measures are required to ensure the security and safety of the cargo. These include the monitoring of cargo shift, leaks, moisture, and temperature using various sensors, cameras, alarms and robotics. Additional deployed technologies will include AI, IoT, Radio Frequency Identification (RFID), drones to substitute human inspection, and intelligent software system that would conduct automated stability calculations with respect to loading and unloading.

When considering operational control technologies, MASS operating in deep seas are likely to be exposed to risk, either internally, such as flooding or fires, or externally, such as ship collision, stranding or grounding. Seafarers typically maintain a ship's seaworthiness. They prevent and control fire, flooding, pollution and even conduct Search and Rescue (SAR) or offer assistance to other ships or persons in distress. While MASS-associated automation is expected to increase safety and minimize human error, particularly in navigation, other issues will arise, such as dealing with fires, explosions, and flooding without human presence.[19,20] Technologies that support automation within these areas are various, such as the use of robotics, drones, Micro Aerial Vehicles (MAV), actuators, cameras (optical cameras and CCTV), AI-assisted software and various sensor hardware (e.g. to monitor the trim, heel, draft, and integrity of the hull and watertight doors). It has been suggested that MASS when encountering persons in distress, could take measures including, contacting and informing SAR services and releasing life rafts or lifeboats.[16]

MASS hulls also differ from conventional ships. Once hull mechanical systems are automated, new technologies, e.g. robotics, actuators and decision-making software, are required to substitute seafarers. For example, once a MASS is moored, lowering the anchor would be done automatically through actuators and AI-assisted software. The same will be the case when the ship is unmoored.[21] Innovative hull designs would take advantage of the reduction or removal of crew accommodation, including the bridge, allowing ships to become smaller, more flexible and efficient in their designs. Damage stability requirements for MASS may even change, leading to the acceptance of a lower subdivision index.[22] Hull designs will need to be compatible with port technologies, e.g. automated mooring and cargo handling systems, to facilitate berthing and unberthing in addition to conducting swift manoeuvres without the need of human intervention. Importantly, considering MASS may have either fewer or no seafarers on board, hull designs must be resistant to piracy attacks and armed robbery as well as protected against illegal trafficking and smuggling (unauthorized stowing of illegal and illicit cargos).[23] This requires the application of various technologies and design elements, such as curved surfaces; barbed wire; monitoring cameras; CCTVs; alarm systems and sensors; and anti-piracy weapons, e.g. long-range acoustic devices, anti-piracy laser and water cannons.[16]

### 3.1.1 OVERARCHING AUTOMATION TECHNOLOGIES

The following overarching technologies are essential to MASS automation (Section 3.1.). AI and system integrators are furthermore needed in all the systems and subsystems of MASS.

#### Artificial intelligence

Artificial Intelligence (AI) improves the performance of machines, enabling them to exhibit human behaviour. Advanced AI furthermore facilitates providing rapid analysis and decision-making that goes beyond human capability. Here, information is processed using machine and deep learning algorithms to make decisions autonomously. With MASS, AI technology forms the core of decision-making capabilities, facilitating autonomous navigation, remote operations, control, repair and maintenance, operation control, cargo management and communications. AI is highly dependent on a number of other technologies, e.g. sensors, particularly condition monitoring, situational awareness, communications, connectivity and cybersecurity. AI not only offers the potential to support uncrewed ships, it can also be adapted to supports crewed vessels where AI-assisted software, such as a virtual assistant, will support command decisions by delivering real-time and contextualized information to the crew when needed.

#### System integrator

Traditionally, shipboard systems were designed as stovepipe systems that lacked the ability for connectivity. This has only recently been addressed with the development of new system integrator functions.[10] This technology brings together instruments and control components from different Original Equipment Manufacturers (OEMs) to establish the required mix of outputs, functions, levels of interconnection, computer program storage, controls, and user interfaces.[10] MASS systems comprise physical components that can be monitored, controlled, and optimized by smart sensors, advanced software and actuators. The interconnectedness of the various systems, including those of third-party providers, are vital to ensuring that the sensors and software are reliable enough for safe ship operations.[12] With MASS, system and subsystem integration is indispensable and essential for safety and interoperability.[24]

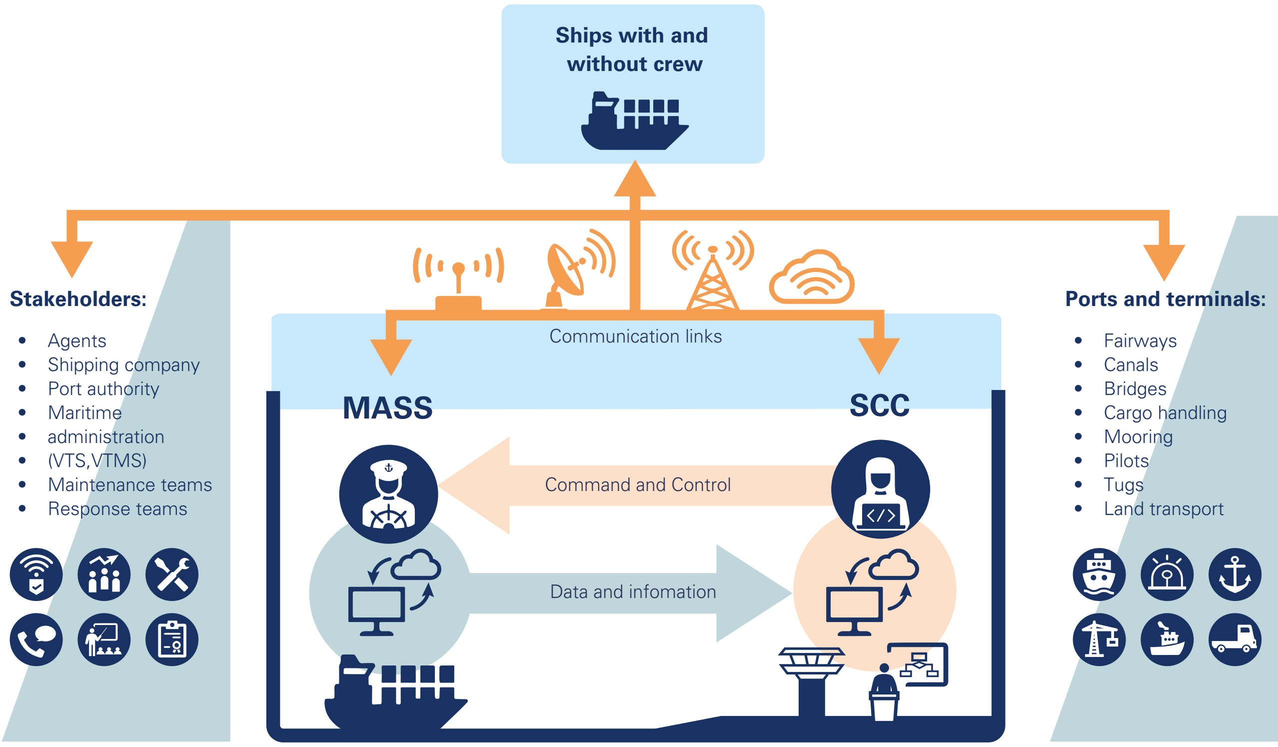
#### Shore Control Centres

Shore Control Centres (SCCs) can be used to supervise conventional ships, yet are indispensable for MASS.[25] A SCC is a site remote from a MASS where the monitoring and/or control of some or all of the ship functions can be executed.[25] SCC operators assume the responsibility of operating autonomous ships successfully and safely by conducting pilotage, traffic services and risk management. The tasks and responsibilities of SCCs may differ based on sea areas, types of traffic, ship segment, and user company requirements.[10,26] In addition, SCC operators will have access to various traditional technologies similar to those a seafarer use on a conventional ship, e.g. traditional navigation systems, which would be enhanced by Virtual Reality (VR) and Augmented Reality (AR) to gain a better and wider picture and maintain full control.[23]

## 3.2 COMMUNICATION TECHNOLOGIES (CONNECTIVITY)

Advanced communications improve a ship's operational efficiency (e.g. logistics monitoring, energy efficiency, route planning, etc.).[17] Communication technologies are key to the safety and reliability of operations, particularly in MASS.[27] Various future technologies are set to enhance the connectivity of a ship both internally and externally. MASS, and to a certain extent advanced-connected conventional vessels, communicate and exchange data and information with other ships (ship-to-ship) by sending data from shipboard equipment to SSCs (ship-to-SCC) and Cloud storage, while also receiving data and command information from SCCs.[28] Generally, MASS communication requirements include communication network redundancy, sufficient power supply and the integration of onboard systems, including software architecture and security encryption.[29] Notably, in addition to the benefits offered to operational communication (e.g. safety, security, and efficiency in operations), the requirement of high connectivity also aligns with the personal needs of seafarers, crews and passengers. Infotainment-level connectivity (i.e. 1.5 Mbps) sustains interaction with family and friends.[30] Arguably, the challenges that seafarers witnessed during the COVID-19 pandemic, e.g. crew change and repatriation

FIGURE 2.4 MASS components and connectivity




issues, would have been less severe if infotainment-level connectivity had already been operational.[31] In addition, since remote and isolated daily life at sea deters potential young talents from joining the commercial fleet, broadband Internet[b] access would be a major pull-factor for potential seafarers.[32]

Reliable high-speed connectivity will facilitate advanced degrees of autonomy for both MASS and conventional ships (Figure 2.4). Improved connectivity (MASS or SCC) will, for instance, facilitate operational communication with ports and terminals, including automated cargo handling, laser-guided mooring systems, tugs, pilots, fairways and other aids for navigation, bridges and lucks controllers in addition to land transport. The same will apply to communications with other ships (whether MASS or conventional) and stakeholders, e.g. ship managers, operators and owners, port authorities, maritime administrations (e.g. Vessel Traffic Service (VTS), and Vessel Traffic Management Information Systems (VTMIS)), as well as maintenance departments and response teams (in ports or offshore). Through improved communication and connectivity, MASS can furthermore generate direct situational awareness information and other data not only from SCCs but also from shore-based radars and other sensors and technologies.[25]

### The internal and external communication systems

Future internal communication systems will require onboard databases,[33] ship gateway system software (for interoperability among various heterogeneous communication links), spectrum and interference management software (access to the national cellular spectrums in national and international waters) and connectivity management systems for integrated satellite-terrestrial communications. Additionally, future ship systems and sensors will require wireless technologies, including, Bluetooth, WALAN, Wireless Fidelity (WiFi), Wireless Mesh Networking (WMN),[c] and optical systems, such as Light Fidelity (Li-Fi[d]).[34]

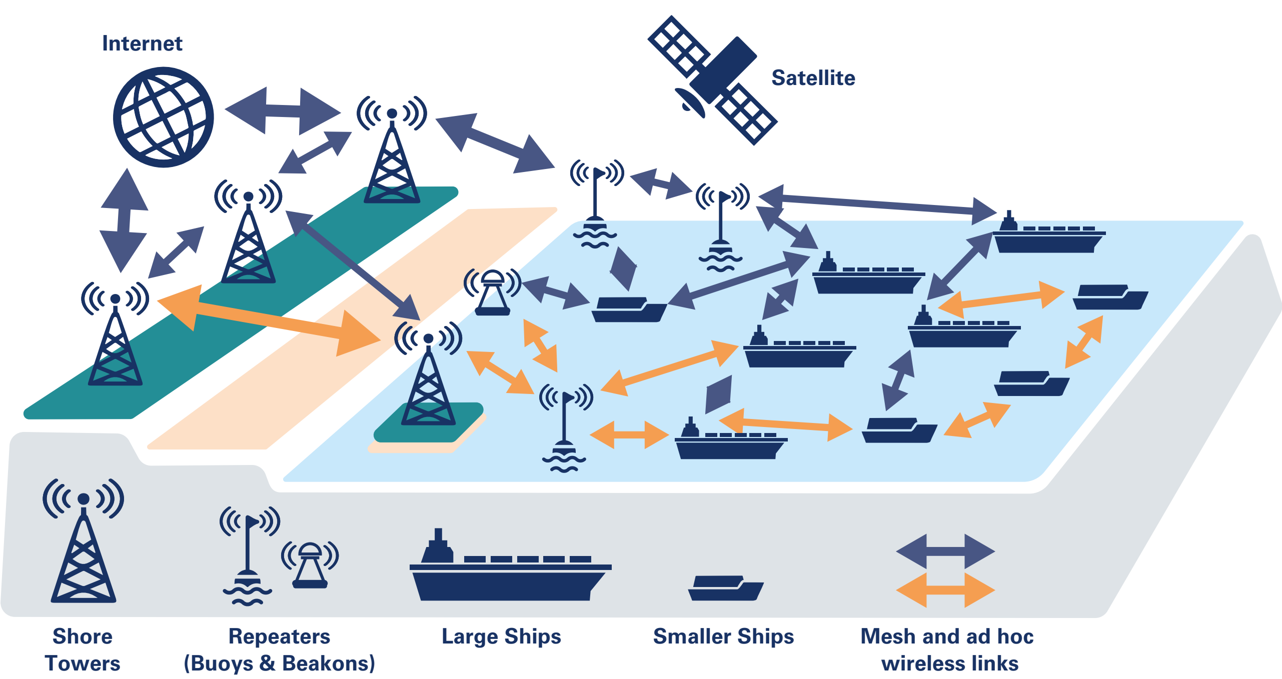
External communication connections include terrestrial and long-range satellite communication systems. These external communication systems will interwork so services are provided seamlessly to ships with different radio interfaces, whether MASS or conventional ships. Terrestrial connections will be used close to shore and in-line-of-sight

[b] See the case study of Panamanian ship (the use of Internet on board ships: investigation of its influence on OSH of seafarers

[c] An important technology used for automatically establishing multiple paths through a network based on the available connectivity[45]

[d] Light Fidelity (LiFi) is a wireless communication technology which utilizes light to transmit data between devices at high speeds over the visible light, ultraviolet, and infrared spectrums

FIGURE 2.5 Maritime mesh and ad hoc network



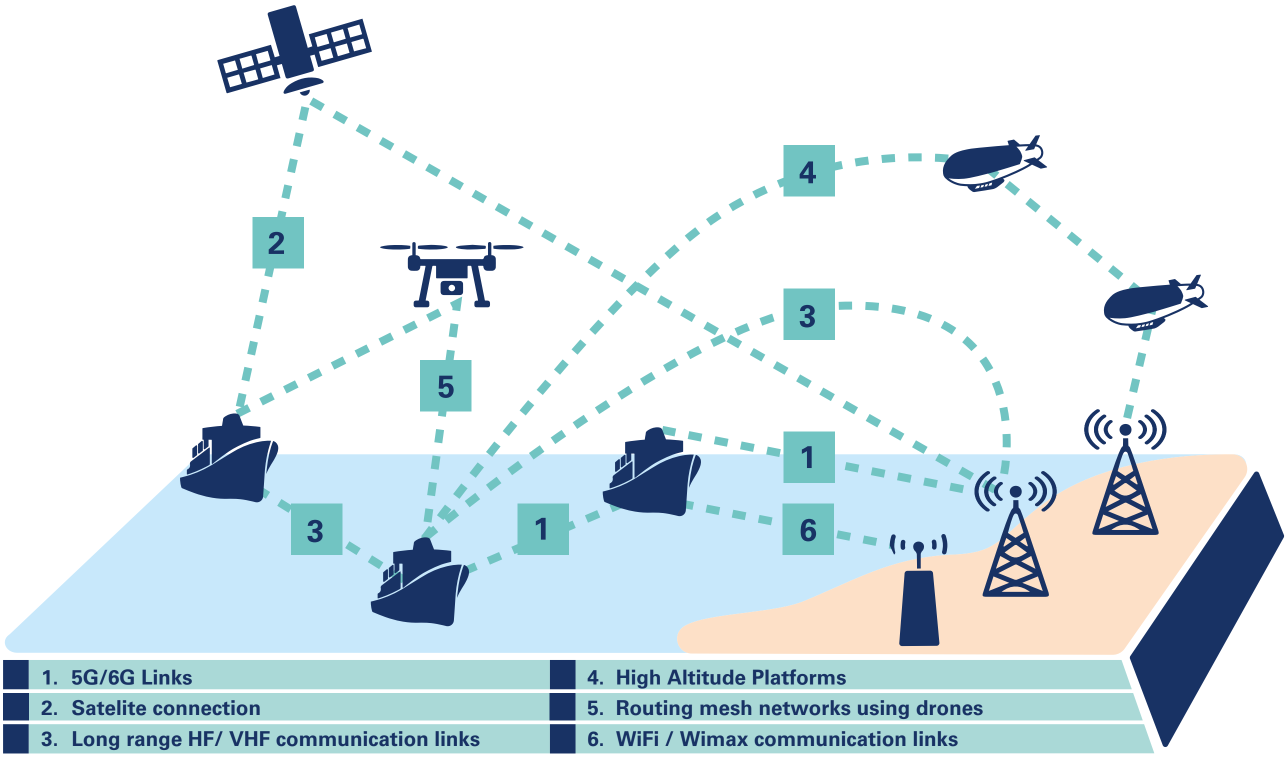

Adopted from [36]

communications will be applied between individual ships and shore-based entities, including SCCs, by use of cellular networks, e.g. Long-Term Evolution (LTE); 4G; 5G, 6G);[27,34,35] wireless communications, such as WiFi and worldwide interoperability for microwave access (WIMAX[e]);[23] High Frequency (HF) and Very High Frequency (VHF) radios; crewed-to-uncrewed ship communications (VHF, WiFi, and 5G radios); mobile wireless mesh; and ad hoc networks (Figure 2.5).

Satellite communication links, on the other hand, are the only solution currently available to provide long-range communication coverage and Internet services.[37] There are around 4,600 satellites in Earth orbits, nearly 2,000 of which are operational as of 2018.[38] Current satellite links are relatively slow and expensive,[39] and when used for MASS there would be some delays.[40,41] Satellites can offer reliable communication systems by operating as a fall-back solution should problems occur with terrestrial systems.[42] These links help ships transfer and receive data and information with high bandwidth, allowing them to enjoy constant connectivity including Internet access, which is important for internal communication systems and to meet current and future international regulations and legislation. High-throughput satellites that provide around 4 Mbps bandwidth meet MASS operations requirements,[35] which is why integrating satellite communications in maritime transport is of great importance. This will facilitate the transmission of the large amounts of data required for remote and autonomous operations of MASS and will ensure safe operations in high seas.[43] Several complementary satellite networks with Geostationary Satellite Orbit (GEO), Highly Elliptical Orbit (HEO), and Middle and Low Earth Orbit (MEO/LEO) systems offer the capacity to provide excellent communication for conventional ships as well as MASS.[23] The following Figure 2.6 summarizes the hybrid architecture of future communications, which will serve MASS and other ships. Future communications will additionally need to include High-Altitude Platforms (HAPs) and the use of drones for sensing and connectivity, including beacons and buoys to boost connectivity.[34]

[e] WiMAX is a family of wireless broadband communication standards based on the IEEE 802.16 set of standards, which provides multiple physical layer (PHY) and Media Access Control (MAC) options.

FIGURE 2.6 Future maritime connections




Adopted from[34,44]

## 3.3 CYBERSECURITY TECHNOLOGIES

Cybersecurity technologies include processing and practices that in combination facilitate the protection of networks, computers, programs and data from attack, damage or unauthorized access.[45] They protect against intentional attacks on software systems that aim to intercept, steal, deceive and disrupt data/ information. In 2016, IMO defined the key areas of cyber-related risks in the maritime sector to include: bridge systems; cargo handling and management systems; propulsion and machinery management and power control systems; access control systems; communications systems; and personnel.[46] Internet connectivity technology, such as wireless and broadband networks (4G, 5G, LTE), makes ships vulnerable to cyberattacks.[23,35] Any failure of ship systems, including communications, may compromise the ship's safety and operations. Secure communication links are therefore vital to avert external interference where unauthorized entities gain full control over the ship, particularly in the case of MASS. Remote cyberattacks include: code injection into critical systems (e.g. malware, ransomware, spyware and viruses), tampering and modification with onboard sensors and equipment or Global Positioning Systems (GPS) spoofing, Automatic Identification Systems (AIS) signal jamming, and communication link eavesdropping and disruption.[47,48] Such breaches of security pose a risk of leakage of sensitive information regarding cargo and costumers.[32] Remote attacks can be prevented through up-to-date protection against virus and malware and by applying maritime network-partitioning techniques to limit broadcast traffic.[47] The segregation of network designs for internal communication is important when seeking to prevent failures from spilling over into other networks. This can be achieved by the use of air-gap, VLAN and firewalls technologies.[49] Similarly, the encryption of links and the use of a Virtual Private Network (VPN) through satellite providers will prevent eavesdropping attacks on communication links between the ship and shore.[47]

## 3.4 DIGITAL AND INTELLIGENT INFORMATION TECHNOLOGIES

Intelligent Information Technology (IIT) involves technologies that employ high-level information processing activities for cognition, learning, reasoning, and decision-making.[21] Such technologies enable the interworking, integration, and sharing of all kinds of data between a ships' internal systems and external resources by means of ICT. Industrial digitalization transforms traditional information handling approaches into data-driven applications.[50] Intelligent information systems would improve ship data collection, computing, analytics, and connectivity, e.g. mobile applications, Clouds, Big Data Analytics (BDA), edge computing, and IoT for smart and autonomous ships.[21,50–52] IIT and ICT enable the digitalization and automation of ships by applying maritime analytics, i.e. understanding, predicting, advising, and improving of maritime activities by digital means.[53]

### Internet of Things (IoT)

The Internet of Things (IoT) is defined as the "worldwide network of interconnected objects uniquely addressable, based on standard communication protocols, which allows people and things to be connected Anytime, Anyplace, Anything and Anyone, ideally using Any path/ network and Any service".[52] The technology therefore not only connects physical objects but also facilitates the creation of new functionalities and values by use of data generated by the interconnected entities.[21] Applied to shipping, the concept of the Internet of Ships (IoS) refers to the network of interconnected maritime objects, either physical or infrastructure, that either belong to the ship, port, waterways, or the wider world of maritime transport.[52] On ships, IoS interconnects sensing and monitoring devices (cargo, machinery, navigation, etc.) through heterogeneous communication technologies to enable the collection, sharing and exchange of data for processing internally and externally (ship-to-ship/ship-to-shore), which ultimately opens the shipping industry to intelligent applications that enhance safety; route planning and optimization; collaborative decision-making; environmental monitoring; and energy-efficient operations.[52]

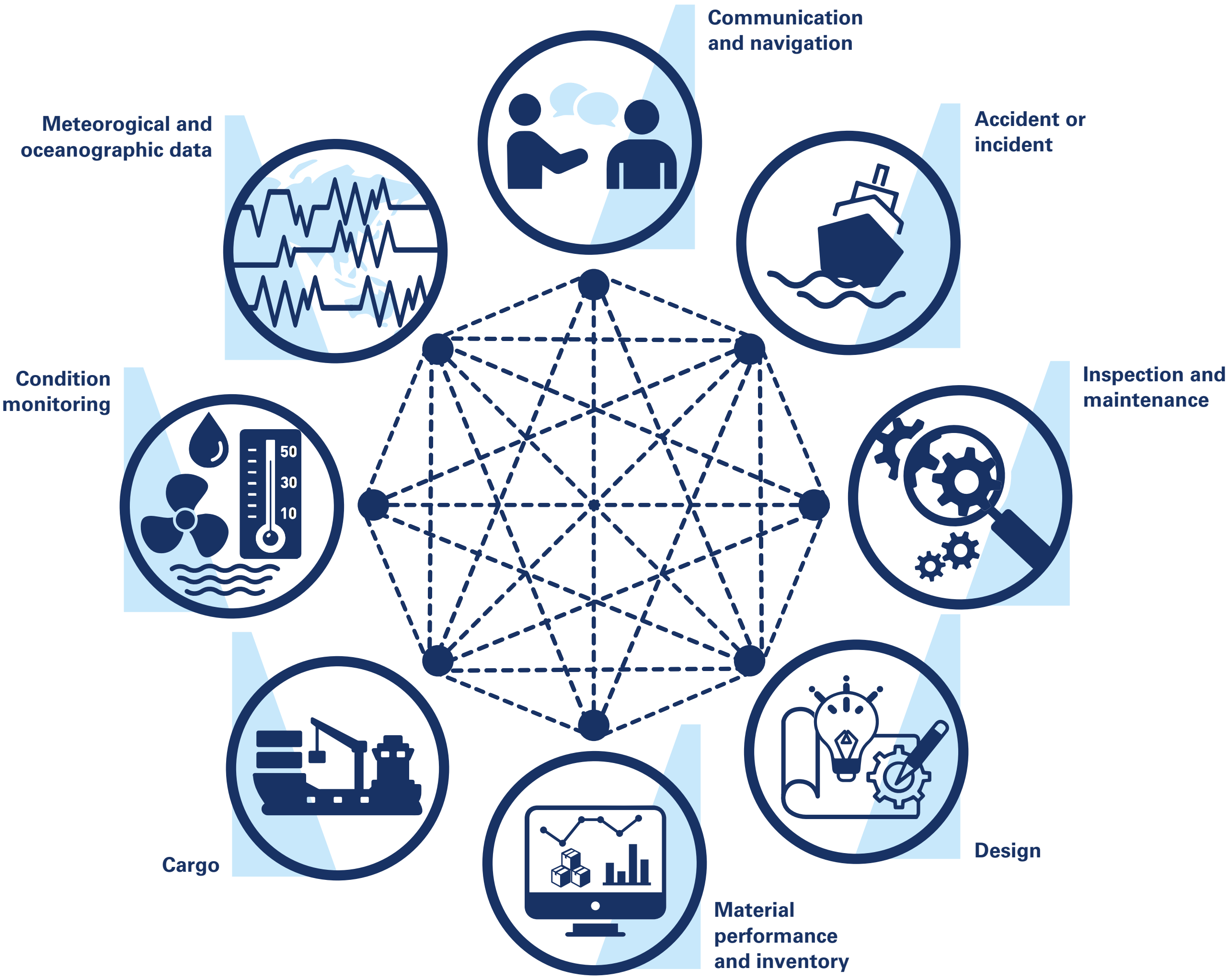
### Big Data Platforms

Ship operations on a day-to-day basis produce huge amount of data, structured and unstructured, with high velocity and different attributes, e.g. traffic data, material and machinery performance data, data on global cargo flows, maritime accident data, and even the personal data of passengers and seafarers. This data can be collected from various onboard and onshore sources and stored on the ship, on land or in the Cloud as large, complex datasets. The value to operators lies in the volume of data, which traditional software may not be able to process adequately.[51,52] Big Data Platforms (BDP) process data generated by sensors, devices and other objects to provide in-depth analyses and data mining (e.g. statistical analyses) that facilitates automated decision-making.[21] BDPs also build their analyses on data on the position of the ship as well as others ships in different fleets.

### Big Data Analytics

Big Data Analytics (BDA) is the process of analysing big data to reveal hidden patterns, correlations, ambiguities, market trends and other beneficial information.[9] BDA can be used in decision-making regarding design, maintenance, condition monitoring, accidents, and cargo management, see Figure 2.7. Data stored internally can be analysed using various AI algorithms and other software that provide quick analysis and decision-making – i.e. onboard data analytics – and support real-time ship operation, such as with edge servers.[34] Big data stored on shore can be interpreted by different services application and analytics algorithms (deep learning) to improve decision-making or even access specific data quickly online/offline.[21,51] Examples are improvements in energy and operational efficiency and safety. Overall, BDA improves the capacity of seafarers to perform efficiently and enable sustainable operations, while maintaining safety of navigation. Examples include issuing seafarers with real-time warnings and alerts to assist them with fault finding.[51]

FIGURE 2.7 Multiple connections of BDA




Adopted from [9]

## Cloud services (storage, IT services, and edge computing)

On-demand Cloud services provide a range of interconnected services. Without the need for local servers, the Cloud allows you to store and access data anytime, anywhere using wireless mobile terminals and the Internet,[21] mostly as a pay-as-you-go service with high security. Cloud service deployment models are divided into public, private, and hybrid services. While some data analytics are conducted onboard, customized applications, computing and analytics services can be accessed online via the Cloud.[52] In addition, Cloud services enable the upload and storage of big data as well as the sharing of data and information among various stakeholders.[21] Cloud services are advantageous due to their high processing power and storage capacity. The raw data and analytics can be accessed by ships and shore services when connected to Cloud services.[52] [f] Data can furthermore be shared with SCCs as well as other ships and stakeholders on shore (e.g. shipowners, operators, VTS, ports, authorities, etc.).[51]

## Blockchain

Blockchain technology is considered one of the foremost technological advances of the Fourth Industrial Revolution (FIR). A gamechanger, the technology facilitates the real-time tracking and management of logistics activities and assets within the whole supply chain, thereby enabling safe data sharing among relevant parties through data sovereignty without the use of paper documents.[54] Blockchain is defined as a "distributed database solution that holds a continuously growing list of data records, which must be confirmed by all participating nodes, and in order to be recorded in the chain, transactions have to be confirmed by the nodes participating in it".[55] Overall, blockchain is considered one of the primary technologies facilitating digital transformation with the potential of addressing industry concerns regarding trust, data integrity, traceability and transparency, inclusion of smart contracts and timeliness. Within the maritime domain, blockchain will allow shipping companies to differentiate their services and reduce costs and save time. The technology reduces paperwork and streamlines processes, while

[f] Satellite and terrestrial communications (LTE and 5G) support the clouds and edge computing services

interconnecting with information technologies to authenticate and validate information.[56,57] Blockchain technology in the maritime industry supports the following services and functions: 1) Electronic bills of lading (e.g. bolero, cargoX, Tradelens), 2) Ship operations (e.g. reducing paperwork, enhancing information sharing, track-and-trace information, distributed ledger platforms), 3) Ship finance (e.g. cross-border payment, ship financing, escrow account), and 4) Marine insurance (e.g. underwriting, claims fraud reduction).[56]

**Digital twinning**

In the digital era, the fast-growing computing and gaming industries facilitate the development of scale models in a virtual environment. The digital twin is seen as one such technology, which can be defined as "a virtual replica of a physical item that replicates actual physical assets, with the added functionality of integrating processes, people, systems, and devices (e.g. actual control system software and emulated control system hardware)".[54,58] Digital twins have three important characteristics: 1) They imply a virtual model that corresponds to a physical model, 2) They offer real-time connection between all sources (sensors, working conditions, location, positions, etc.), and 3) They support data visualization. In brief, the digital twin is a precise visual copy brought to life by feeding real-time data streams into the model, while integrating these streams to make the model come to life. In shipping, a digital twin of a real vessel requires the inclusion of mathematical models of the physical ship; ship-specific dynamics; power system; propulsion system; positioning system; ballast system and sensor systems; the control systems, such as dynamic positioning; automation systems; and autonomous and remote navigation systems.[58]

**3D and 4D Printing**

3D printing (also termed additive manufacturing), implies prototyping and manufacturing by applying successive layers of materials.[59] 3D printing enables the manufacturing of objects with complex geometry, e.g. non-linear holes and honeycombs that traditionally incur high production costs.[9,60] 4D printing principally differs from 3D printing by allowing the printed object to morph itself into different forms in response to ongoing environmental stimulus, thus becoming a time-dependent product.

3D and 4D technologies aim to deliver high-quality, low-cost products and systems by applying emerging technology, such as open source designs.[9] 3D technology is also applied when producing items of size, such as vehicles and aeronautical components, while maritime manufacturing has utilized 3D printing to produce adaptable hull forms to address issues resulting from changes in a ship's loading conditions and speed profile.[9] In-situ 3D printing and 4D will furthermore be introduced to produce critical items on board ships.[9] 3D technology allows organizations, or even the ship itself, to gain access to archives of digital designs for immediate in-situ printing rather than maintaining physical inventories of spare parts and/or waiting for orders to be transported.[61] This is particularly useful in the event where components for older or obsolete machinery are required. Overall, 3D printing will be beneficial for onboard maintenance and repair.

**Augmented Reality (AR) and Virtual Reality (AR)**

Virtual Reality (VR) creates a 3D computer-generated environment that a user can explore and interact with. These virtual environments can either be projected onscreen or through head-mounted displays. VR facilitates immersion into a virtual world coupled with simulation. The technology is still not widely used with maritime simulators, although when applied they allow trainees to acquire virtual experiences across vessel operations and maintenance and repair undertakings, while gaining insight into surveying, risk management and emergency and evacuation procedures. Augmented Reality (AR), on the other hand, allows data from virtual systems (e.g. a digital twin) to be visualized in the real world where appropriate. AR is beneficial to manufacturing processes as well as maintenance tasks since it supports the visualization of hidden areas. VR and AR apply haptic technologies (3D graphics), which provide tangible touch sensations for the operator through mechanical load (i.e. forces, rotations, motion, etc.) thereby facilitating the association of an action with its physical consequences. Future technologies may even include olfaction (smell) technologies.[12,62,63] AR and VR equipment includes headsets, tablets and interactive flat-screen displays, caved and curved wall displays, and hemispheres and dome displays, which in the future can be applied at the bridge by watch officers, thereby enabling immersive 3D representation.[23,38]

## 3.5 ZERO-EMISSION TECHNOLOGIES (DECARBONIZATION TECHNOLOGY)

Minimizing fuel consumption and reducing carbon emissions through various technologies and energy efficiency initiatives have become a major priority for the maritime industry, not least in light of the forthcoming IMO regulations, i.e. the Energy Efficiency eXisting Ship Index (EEXI) and the Carbon Intensity Indicator (CCI).[64] The IMO target is to reduce the carbon intensity of shipping by 40-70% by 2040 and 2050 respectively and the total GHG emissions by 50% by 2050. Currently, technical and operational measures are utilized to improve ship energy efficiency (e.g. trim and route optimization, propeller and hull technologies, etc.). However, radical innovation and Step-Change technologies are required to transit shipping into becoming zero or near-zero carbon emitters. Decarbonization technologies include cleaner fuels, alternative fuels, battery-powered and hybrid propulsion, nuclear fuels, shipboard capture of renewable energy and exhaust treatment technologies.[63–68]

### Cleaner fuels

Cleaner fuels include Liquefied Natural Gas (LNG), which is considered one of the pathways to reduce $CO_2$ emissions, while at the same time comply with $SO_x$ and $NO_x$ requirements (i.e. the reduction of air pollutants). The $CO_2$ emission reduction potential of LNG is 20–30% compared to conventional fuels. However, this relative reduction in $CO_2$ emissions may be compromized by methane slip. LNG is commercially advantageous and available worldwide in quantities that can meet the fuel demand of shipping. The number of ships fuelled by LNG is growing considerably. Similar cleaner fuels that reduce carbon emissions are Marine Gas Oil (MGO), and Liquefied Petrol Gas (LPG).

### Alternative fuels

Alternative fuels include biofuels that are biodegradable and offer the potential to deliver a large $CO_2$ (GHG) emission reduction. One advantage is using biofuel as a 'drop-in' fuel, i.e. blended with conventional fuels, thereby requiring very little engine modification.[65,69] The main challenge with the adoption of these biofuels on a large scale is securing the required production volume. In addition, the overall emissions reduction potential is questionable owing to air pollution issues during crop cultivation when creating biofuel. The use of waste oils could potentially alleviate these issues but the limited availability of such waste oils is another challenge.

As is the case with other alternative fuels, methanol and ethanol are still in their early stages of market introduction. Methanol can be used in marine engines, such as in dual-fuel engines. However, the fuel yields a modest $CO_2$ emission reduction.[65,70] There are many sources that contribute to the production of methanol, e.g. natural gas, catalytic hydrogenation of a waste $CO_2$ stream, and biomass. Ethanol and more traditional fuels, such as Fatty Acid Methyl Esters (FAME), and even non-traditional fuels, such as glycerol, are also considered alternative fuels.[45]

Hydrogen as a fuel is largely used in fuel cells, which can efficiently generate low-carbon electricity using the chemical energy of hydrogen, or other fuels. Fuel cells are more efficient in their electricity production than traditional engines, i.e. up to 60% efficiency compared to 40% in conventional engines.[63,69] Drawbacks associated with hydrogen are concerns about emissions during production, transport, storage and use (planned or unplanned releases) of hydrogen in addition to the investment costs in related infrastructure and ship retrofitting as well as safety concerns. Commercial ships that carry hydrogen are required to comply with the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code). However, the IGC code does not currently permit the transportation of liquid hydrogen. Finally, ammonia as an alternative fuel could potentially be used directly in marine propulsion engines, either for combustion or in a fuel cell. Ammonia is produced using three main components – power, air and water – in a process that extracts nitrogen from the air using electricity. Nitrogen is then combined with hydrogen. However, sufficient supplies of ammonia for shipping are not yet available.

### Battery electric and hybrid propulsion [g]

Electric Propulsion (EP) systems include an electric motor supplied with electric power from an energy storage system such as a battery.[62,63,65,70] Battery technology is experiencing rapid innovation driven by demands within other sectors. Recent breakthroughs include lithium-sulphur, lithium-air and aluminium-ion batteries.[45] The same applies to graphene batteries. Despite such recent and anticipated technological advances, batteries have a significantly lower energy density per volume and mass than fuels. An emerging technology that will complement batteries is the supercapacitor (also known as the ultracapacitor). Future supercapacitors are likely to be widely used, predominantly when there is a necessity to rapidly store and discharge large amounts of electricity (e.g. graphene supercapacitors).[45] Developing the required infrastructure at ports and on board (e.g. charging systems) could improve the shipping industry's potential to decarbonize. Furthermore, hybrid electric systems are already available that combine internal combustion engines with batteries, which is particularly suitable for electric drives (e.g. diesel-electric systems).[12,69] However, there is still a need for advanced batteries that support long-range voyages in oceangoing vessels (beyond 2050 technology).

### Nuclear fuels

Nuclear fuels offer high-power density with less emissions of GHG and air pollutant and with stable fuel prices. Furthermore, nuclear engines can operate for long periods of time without the need for refuelling. On board ships, nuclear power for propulsion can be produced via a small nuclear plant that heats water to drive steam turbines and turbo generators.[69] While popular in the navy fleet, the management of nuclear material is of substantial security and geopolitical concern within shipping. Thus, a development of commercial civilian nuclear vessels faces public, political and legal barriers. Other issues are safety in the event of catastrophic incidents (liability issues), radioactive pollution to air and water from fires or the sinking of nuclear-powered vessels, terrorism and the non-proliferation of nuclear activities.

### Shipboard capture of renewable energy

Wind and solar energy generation offers the potential to reduce GHG emissions. Plans have been announced to operate a wind-powered car carrier ship by 2025 where wind is to be used as the main energy source for propulsion.[h] This concept aims at a 90% emissions reduction and primarily relies on wind power with an auxiliary engine for backup. When wind is used as the primary power source, ships are typically designed to operate at lower speeds than conventionally powered designs. Wind power may be applied to newly-built as well as retrofitted ships and may also be used as a backup power source to existing power generating systems,

[g] See the case study of a Swedish ship (the use of batteries as an alternative to propel the ship: the Swedish paradigm)

[h] https://www.theoceanbird.com/the-oceanbird-concept/

i.e. as a wind-assisted ship propulsion system (WAPS).[65,70] Wind power generation includes the use of Flettner rotors, kites or spinnakers, soft sails, wing sails and wind turbines. Solar energy could make another significant contribution to onboard energy requirements. On a global scale, its potential contribution is lower than that of wind power but its potential also depends on the routes on which a vessel operates. However, the erosion of solar panels by the salty marine environment is a barrier to its adoption. Another renewable energy source is the utilization of ocean energy. A growing number of companies are attempting to exploit innovative power solutions to harvest energy from wave motion.

**Exhaust treatment technologies**

Treatment of exhaust gasses is another option to decarbonize ships, although the technology is still under development and includes Selective Catalytic Reduction (SCR), Ammonia Slip Catalysts (ASC) and Exhaust Gas Recirculation (EGR). The further development of Methane Oxidation Catalysts (MOC) would also improve the potential of such technologies (decarbonisation).[63] Additionally, Carbon Capture and Storage (CCS) systems can also be applied to reduce $CO_2$ emissions. CCS tackles carbon emissions at its source: exhaust gas.[9,12,45,62,65] The technology is not widely used and very few commercial plants on land are available for the sole purpose of emission reduction. The slow progress of this technology is owing to high capital requirements and operating cost as well as a lack of incentives and a non-existent $CO_2$ market.[63] From life-cycle perspective, the technology is considered energy intensive and seen as shifting emissions from one sector to another. Nonetheless, research into how this technology can be utilized in shipping is progressing.

**Alternative fuel bunkering**

The bunkering of alternative fuels, such as LNG, ammonia, methanol and hydrogen is considered an important contributor to the future decarbonization of shipping.[64,71] Bunkering infrastructure is to be established by shore-side stakeholders, including ports, maritime authorities and third-party energy providers, which may see an interest in the provision of sufficient supplies of alternative fuels to calling ships to maintain their port business and so ships can continue normal operations.[66,67]

## 3.6 ADVANCED SENSORS

Future ships will be smart and utilize sensors installed in e.g. the hull, main engine, auxiliary machinery, on cargo and even on small items of equipment, thereby generating big data that can be processed either on board or on shore and ultimately support decision-making.[65] Sensors will survey the ship's surroundings, such as the physical environment (ocean data), including biological, acoustic and electromagnetic characteristics, and the conditions and characteristics of the ship itself. Indeed, even the sentiments of the seafarers can be registered.[9,65] Ships will be monitored throughout by around-the-clock digital watch-keeping using sensor networks. Advanced sensors are enablers of cognitive computing that uses natural language processing and AI to develop interaction between people and machines.[45,62] Overall, sensors will facilitate better situational awareness and vessel management. Future sensors will need to be robust and wireless, such as the new generation of micro- and nano-mechanical sensors. Additionally, sensors will need to be capable of remote sensing, which will require characteristics such as self-calibration, fault tolerance, high transmission and wireless capabilities. Sensors will furthermore be made of environmentally-friendly materials for easy disposal.

## 3.7 ROBOTICS AND DRONES

A robot can accomplish multifaceted and complicated tasks automatically. Robots can, for instance, be programmed to conduct assembly and disassembly, collaborate with humans or machines and execute inspections and exploratory activities. Robots offer various capabilities, including cognition and versatility (flying, swimming, climbing), imitation (human and animal actions), senses (speaking, touching, listening), and adaptability (working in different environmental conditions wirelessly and battery-driven).[9,45] Robots also exhibit different levels of decision-making independency and can be either remotely controlled, supervized, collaborative or even fully autonomous. The development within other technologies, such as sensors, cognition, miniaturization, communication, robot-to-robot communication and motion control, would potentially expand the global use of robotics considerably. The potential in shipping includes: 1) Robots off board can be used as sniffers (monitoring ships emissions), mini surveyors, and searchers that conduct search and rescue activities. 2) Onboard robots can assist with housekeeping and identify and repel threats. 3) Robots can also be used as wearables where they can help crew lift heavy weights, firefight and conduct maintenance tasks in the form of welding, cutting and fitting.[9,12,62]

## 3.8 ADVANCED MATERIALS

The application of advanced materials (e.g. metals, ceramics, polymeric and composite materials) aims to deliver specific physical properties and improve such capabilities as strength, toughness and durability. Advanced materials improve functional characteristics and enable environmental sensing, self-cleaning, self-healing, enhanced electrical conductance and shape modification.[9,45,62] Nano-scale designs – one millionth of a millimetre – and engineering are leading the development of advanced materials. Other materials include Glass Fibre Reinforced Plastics (GRP), aluminium, graphene (single-atom layers of carbon), 3D weaving technologies for composites, Aluminium Oxynitride (ALON), and metal foam.[12,63]

The advantages of advanced materials can be divided into:[9,63] 1) Materials that are fine-tuned at microscale or nano-scale to offer an extraordinary combination of strength and toughness, including malleability, and self-healing, 2) Composite materials that can replace steel, e.g. polymer matrix composites, and carbon fibre-reinforced plastics, which results in lightweight, stronger, anti-corrosion and tougher materials, 3) Bio-inspired and bio-based materials that have chemical or physical properties that protect against external surface challenges, such as abrasion, fouling or icing, and 4) Light, versatile and sustainable materials that can be self-repairing/cleaning, e.g. advanced high-strength steel, aluminium, glass fibre, or carbon fibre composites. Advanced materials can be used in different ways in ships, including as composite materials for superstructures and hatch covers, thermal insulators for cargo holds, self-repairing composite materials for propellers and rudders, ceramic or metal composites for engines, and self-healing materials, advanced anticorrosion, and antifouling coatings for the hull (graphene films).[9]

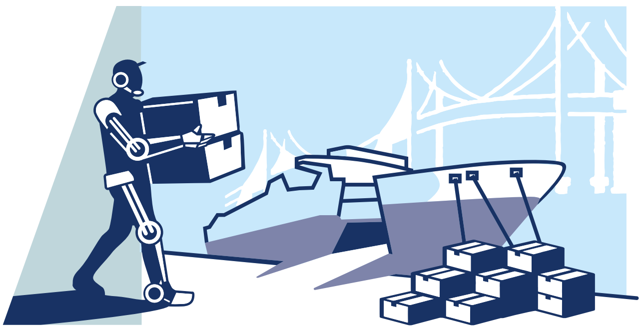
## 3.9 HUMAN–COMPUTER INTERACTION

Human–Computer Interaction (HCI) technologies are designed to facilitate the interface between humans and computers. Currently, workstations that involves human and computers still utilize universal interfaces, such as keyboard, mouse and screen. However, there are important differences between the human brain and computers processing systems, which are mediated by HCI. To achieve this, HCI includes multidisciplinary features from computer and cognitive science, psychology, design, and visualization. HCI technologies are expected to interact with humans smartly, recognizing human requirements, commands, and preferences.[9,12,62,63] This is achieved through gesture and speech recognition as well as eye-tracking. Additionally, future AI-assisted HCI technology may also result in brain–computer interfaces and intelligent virtual assistants with the ability to monitor user behaviour and communicate in natural language. As more automation is introduced in shipping, AR and VR technology will facilitate HCI by use of contact-lens displays and 3D Organic Light-Emitting Diodes (OLED) that supports speech, handwriting, touch and gesture capabilities.

## 3.10 HUMAN AUGMENTATION

Human augmentation (or human enhancement) includes various technologies and is dependent on different scientific disciplines including medicine. The technology aims at enhancing human performance and cognitive capabilities far beyond average levels and to assist in rehabilitating motorial functions lost to injury or illness. Human augmentation comprises pharmaceuticals, implants, prosthetics and exoskeletons. On ships, lightweight modular exoskeleton devices can be used to increase the strength of crew members with specific operations, such as carrying heavy loads, thereby reducing fatigue and injuries (Figure 2.8).[12,45,62] Crews can also be supported by cognitive augmentation devices that can monitor whether a seafarer is operating under stress or fatigue through closed-loop Brain-Computer Interface (BCI). Additionally, the technology may be used to enhance user attention via brain stimulation, a technology called Transcranial Direct Current Stimulation (TDCS).[12,45,62]

FIGURE 2.8 Seafarers augmentation



Adopted from[9]

# 4 FUTURE SHIPPING TECHNOLOGY ROAD MAP

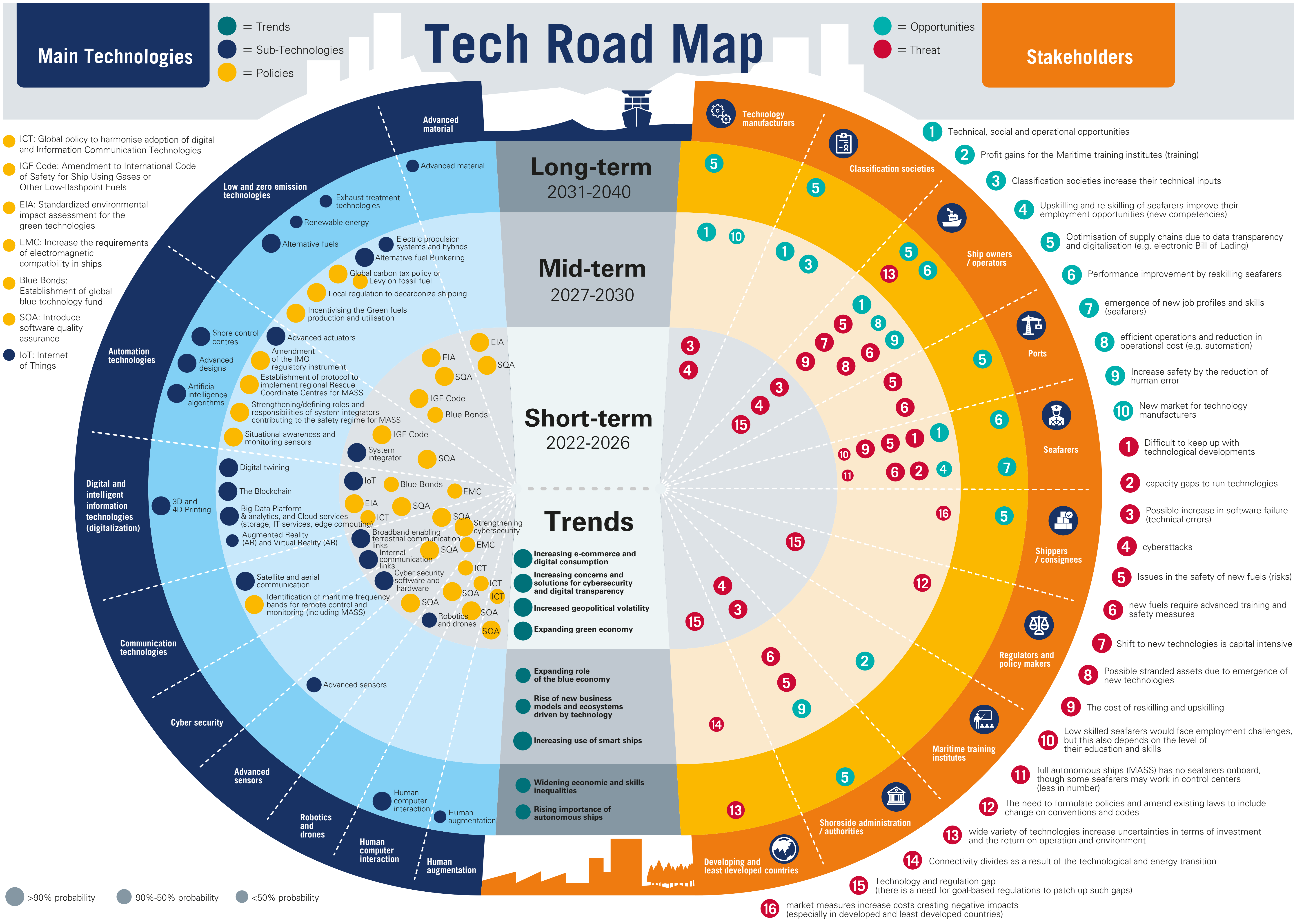
A growing global awareness of sustainable resource usage and climate change action has prompted significant technology development across numerous industries. Maritime transport is no exception. The effectiveness and success of the integration of sustainable technologies would arguably benefit from a more coherent international approach to policy and regulatory measures. The Technology Road Map in this chapter aims to support such a development by offering comprehensive insight into future industrial technologies, including a top-10 list of industry trends that these technologies respond to. The Road Map offers a time horizon and assesses the potential of future technologies, including automation.

The identification of future shipping technologies and automation is of broad relevance to the shipping sector, since the conventional fleet is also set to experience an ongoing upgrade with automation and digitalization to increase safety and efficiency in operations and reduce the carbon footprint of the industry, while providing significant assistance to seafarers in terms of assistive technologies and systems that support decision-making. Furthermore, the identification of technologies and relevant policies, including opportunities and threats, also holds value to maritime stakeholders, enabling them to prepare for and address emerging issues owing to new technologies. Such stakeholders include researchers, designers, shipbuilders, equipment manufacturers, shipowners and operators, ports, policymakers (regulators), maritime educators and seafarers' unions. An important aspect of the preparedness of the industry to adapt to and shape the future of the maritime field is for Maritime Education and Training Institutions (METIs) and shipping companies to adopt plans to upgrade the skills and competencies of seafarers.

## 4.1 STAKEHOLDER-VALIDATED TECHNOLOGY ROAD MAP FOR SHIPPING (2040)

The Technology Road Map has been empirically developed in cooperation with various stakeholders/experts, most of whom have seafaring experience. The participants took part in three workshops. The first was held in situ and the following two were conducted virtually. The combination of experts (50 maritime experts and stakeholders) represented a broad range of maritime expertise, i.e. technologists (28%), academia (9%), Non-Governmental Organizations (NGOs) (4%), shipping companies (6%), shipping associations (14%), shipowner associations (12%), regulators (24%), and others (3%). Following the qualitative methodology of SKOLKOVO,[72] the stakeholders selected the top-10 industry trends (explained in section 2), future shipping technologies (explained in section 3) and the required policies to facilitate technology adoption. After the identification of the industry trends, technologies and policies, the stakeholders further identified the opportunities and threats relevant to various maritime stakeholders as a consequence of trend materialization and technology adoption. The policy list with descriptions is available in Table 2.A in section 4.2. Additionally, the opportunities and threats with descriptions are clustered in Tables 2.B and 2.C in section 4.3. All Technology Road Map constructs (trends, technologies, policies, and stakeholder opportunities and threats) were rated in terms of probability of occurrence (high, medium, and low probability) and the time horizon of adoption (short, medium and long-term horizons). Figure 2.9 illustrates the broad Technology Road Map designed as a circle with one outer and three inner circles. The upper half of the map shows the time horizon and the lower half highlights the top-10 trends. The left side of the outer layer of the Technology Road Map offers an overview of the 10 main technologies and their 26 sub-technologies, which are positioned within their relevant inner time horizon and trend circles. Also highlighted on the left side are the policies relevant to these technologies. The right side of Figure 2.9 shows the 10 maritime stakeholders in the outer layer and the 10 opportunities and 16 threats in the respective inner circles, which are furthermore positioned within their relevant inner time horizon and trends circles. Similar to the sub-technologies listed on the left side of the Technology Road Map, the opportunities and threats posed by these technologies are positioned within the three inner circles related to the time horizons and selected trends. Besides each element of the Road Map is a different-coloured circle, the size of which indicates its probability to occur.

FIGURE 2.9 Technology Road Map



### Technology Road Map Takeaways

Aggregated technologies listed in the Technology Road Map are those that are dependent on the development of other technologies. Through their interdependency and interconnectivity, they offer the potential of creating a new technological paradigm that transforms the way ships are designed, constructed and operated. This technological interoperability and integration is driven by advances within a range of technologies, including autonomous decision-making, AI-enabled BDA and HCI. Other technology drivers include developments within communications, advanced materials and energy management. The success of these new technologies identified in the Technology Road Map will rely on the adoption of an appropriate regulatory framework, global standardizations of technologies, and cooperation and coordination among maritime stakeholders [9]. Indeed, technological readiness in the market not only relies on the technology providers, but also on the active involvement of maritime stakeholders in the future of the industry, including manufacturers, cargo owners, shipowners and operators, port operators, regulators, policymakers at governmental and corporate levels, investors, seafarers, individuals and the public at large.

## 4.2 TRENDS AND TECHNOLOGIES REQUIRE POLICIES

A lack of policies supporting technological transformation is a critical issue that has implications on whether providers see incentives in introducing new technology to the commercial market as well as whether shipowners see an advantage in investing in new solutions. To identify conductive policy areas of future importance (Figure 2.9 and Table 2.A), the maritime stakeholders taking part in the development of the Technology Road Map primarily focused on industry trends related to climate change mitigation. These include levies on fossil fuel, incentives, global Blue Bonds, and carbon taxes. Stakeholders also identified a need for policies to facilitate the integration of new communication technologies such as Electromagnetic Compatibility in ships (EMC), Environmental Impact Assessment (EIA), Software Quality Assurance (SQA), system integrators, cybersecurity, and the identification of new maritime communication frequencies (for remote control). The experts emphasized that technology uptake would likely increase in the maritime industry once regulatory frameworks address the issues that emerge from the application of these technologies. For instance, some new technologies, such as MASS automation, require new regulation since the STCW convention assumes that seafarers are located aboard ships and on watch at all hours. Guidelines for human automation interfaces in ships are also seen as a tool with which to facilitate work-related interactions between humans (seafarers) and machines on different ships or at SCCs. It was also suggested that the IMO STCW convention needs to accommodate the new skills and competencies required for seafarers to align with the requirements of new technologies (e.g. the use of alternative fuels such as hydrogen, ammonia) and furthermore to offer a framework to protect seafarers from the consequences of occupational redundancy. Such implications call for the need to redesign the curricula for METIs where a common framework is required. The Technology Road Map also indicates a need for amendments to be made to SOLAS, MARPOL, COLLREGs, particularly once ships become autonomous. Such policy recommendations, suggested by participating experts align with recent IMO initiatives, i.e. the regulatory scoping exercise, which was established to verify the appropriateness of the existing IMO regulatory instruments (i.e., SOLAS, ISM code, COLREG, STCW, MARPOL, etc.) in relation to MASS, including issues pertaining to safety, security, and the environment.[73] In this scoping exercise, IMO suggested four instruments for the road ahead,[73] namely: amending existing instruments, developing a new separate instrument, creating a combination of these two options, or developing interim guidelines to gain experience before commencing work on mandatory requirements.

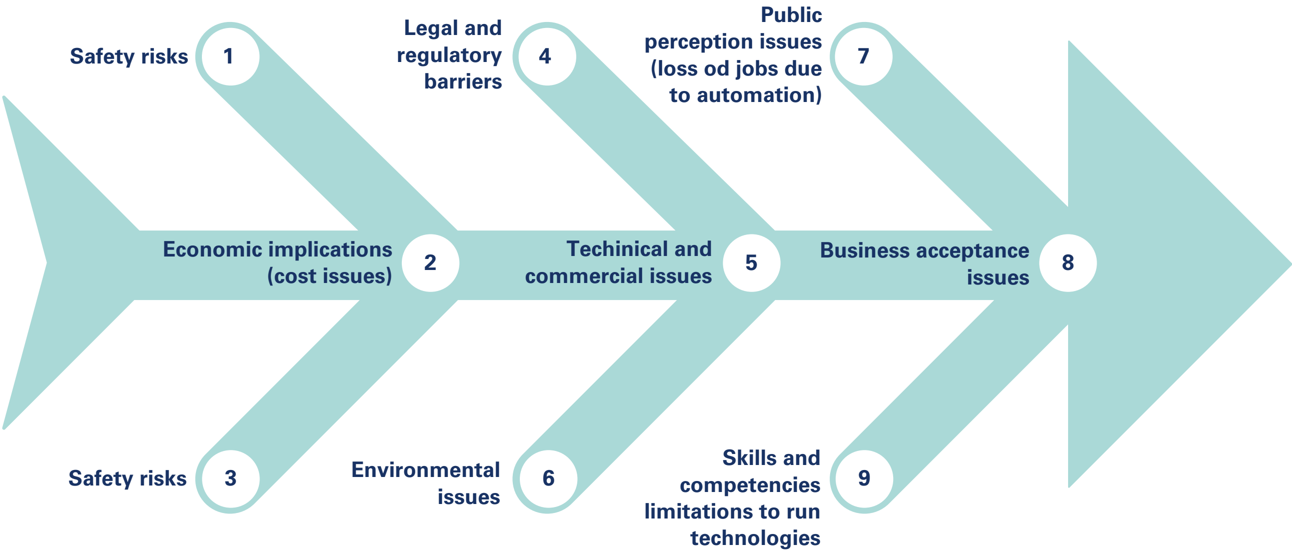
TABLE 2.A List of recommended policies

| POLICY | DESCRIPTION |
|---|---|
| Amendment of the IMO regulatory instrument | This enables the accommodation of MASS in the existing IMO instruments, including new technologies such as alternative fuels |
| Identification of maritime frequency bands for remote control and monitoring (including MASS) | Connecting to terrestrial communication (land) necessitates the establishment of dedicated maritime frequency bands |
| Establishment of protocol to implement regional Rescue Coordinate Centres (RCC) for MASS | This policy calls for a unified and standard framework for regional rescue operations with regard to autonomous ships |
| Amendment to International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels (IGF Code) | There is a need to include other alternative fuels, such as ammonia (NH3), Hydrogen (H2), biofuel and methanol, in the IGF Code since currently only LNG is included |
| Global policy to harmonize the adoption of digital and Information Communication Technologies (ICT) | Standardization and harmonization of Information Communication Technologies (ICT) in a global context , e.g. blockchain, IoT and similar technologies |
| Establishment of a global blue technology fund (Blue Bonds) | Supporting developing countries to adopt digital and green technologies |
| Strengthening/defining roles and responsibilities of system integrators contributing to the MASS safety regime | A policy targeting the mitigation of obstacles in various heterogeneous systems, which calls for standardized industrial guidelines |
| Strengthening cybersecurity | Such a policy requires paying close attention to the issue of cybersecurity (legislation), including support for research |
| Introduce Software Quality Assurance (SQA) | The scope of different technologies and manufacturers requires a SQA to mitigate software issues and enhance interoperability |
| Incentivising green fuels production and utilization | Countries and policymakers need to establish programmes to incentivize the introduction of green fuels |
| Increase the requirements of Electromagnetic Compatibility on ships (EMC) | EMC minimizes the interference of emissions produced on ships with other electronic equipment on the ship or other ships, including onshore equipment |
| Standardized Environmental Impact Assessment (EIA) for green technologies | An EIA should consider alternative fuel production, distribution, and infrastructure |
| Local regulation to decarbonize shipping | Compulsory use of renewable energy and clean energy by calling ships |
| Global carbon tax policy or levy on fossil fuel | This can be achieved by reaching a global consensus on the reduction of GHG emissions. Such a measure would improve the penetration and competitiveness of alternative fuels. The collected funds would finance infrastructure and improve the institutional capacity of the States. Similarly, offering small shipping companies compensation in return for adopting cleaner technologies should also be encouraged. The funding should be clear, transparent and based on a multilateral framework |

## 4.3 THE OPPORTUNITIES AND THREATS OF TRENDS AND TECHNOLOGIES TO VARIOUS MARITIME STAKEHOLDERS

Despite the benefits of adopting new technologies such as automation (e.g. sustainable and efficient operations and the improvement of social aspects and safety), there are equally many barriers that inhibit broad integration. Figure 2.10 summarises the barriers to full-scale adoption of technologies. Concerns about the safety of ships and other security risks in addition to the economic implications are all seen as clear inhibitors. The public perception is that seafarers may risk losing their jobs, particularly if automation technologies are fully adopted.

FIGURE 2.10 Barriers and limitations of technologies




Research indicates that technologies can be a double-edged sword. They can deliver great benefits, but may also introduce both direct and indirect threats to maritime industries, States and economies.[9] Empirically, opportunities and threats, as represented in the Technology Road Map (Figure 2.9), may positively (opportunity) or negatively (threat) influence the decisions of maritime stakeholders.[72] Discussions on emerging opportunities and threats are therefore vital to the future of the industry.

The identified opportunities (see the Technology Road Map Figure 2.9 and Table 2.B) are focused on the benefits to shipowners, operators and technology manufacturers in terms of operational efficiency and new business opportunities. Innovation promises to reduce total costs and streamline transport transactions and supply chains. Seafarers would also benefit by gaining new skills, while maritime institutes could see an increase in their revenues.

## TABLE 2.B List of identified opportunities for maritime stakeholders

| STAKEHOLDER | OPPORTUNITIES |
|---|---|
| Technology manufacturers, classification societies, shipowners/operators, and seafarers | Technologies provide technical, social and operational opportunities in shipping and beyond (e.g. system integrations) |
| Maritime training institutes, educators, classification societies | The adoption of new technologies requires the training of seafarers and improvement of their skills, which increases the revenues and profits of training institutions. Classification societies will increase their technical inputs |
| Seafarers | Upskilling and reskilling of seafarers will improve their opportunities in maritime employment (new competencies). Improving of health and medical services at sea |
| All maritime stakeholders (e.g. technology manufacturers (IT), ship owners/operators, shippers, customs, port authorities) | Data transparency through digital and intelligent information and communication technologies optimizes and synchronizes processes while streamlining the supply chain and transportation procedures (e.g. digital trading (electronic Bill of Lading), paperless trade and use of data and analytics in the decision making) |
| Seafarers, shipowners/operators, technology manufacturer | The adoption of new technologies offer new opportunities in terms of reskilling seafarers for new opportunities and to improve their performance |
| Shipowners/operators | A reduction in the required workforce and operational cost and the improvement of operational efficiency through automation and new technologies |
| Shipowners/operators, shore-side administration | Automation technologies will provide opportunities for shipowners to reduce human error, although new technical errors may emerge |
| Technology manufacturers and providers | New technologies will open markets for technology manufacturers (e.g. new entrants such as software engineering and data management companies) |

Individual maritime experts also identified a wide range of threats that impact the feasibility of new technology and therefore risk influencing the decisions of different stakeholders (Figure 2.9 and Table 2.C). Threats to seafarers include skill gaps. Shipowners and operators would have to face the costs involved in adopting new technologies, reskilling seafarers and the liability of stranded assets, which are threats relative to different factors, such as the current technology gap of their organization. Regulation gaps were also identified that could create uncertainties for maritime stakeholders. Automation may furthermore increase cyber threats both on ships and shore-side.

TABLE 2.C List of identified threats to maritime stakeholders

| STAKEHOLDER | THREATS |
|---|---|
| Seafarers | Upskilling of seafarers to high-technology shipping may be a challenge. |
| Shipowners/operators, manufacturers, shore-side administration | There is an increased risk of software failure and cyberattack |
| Shipowners, seafarers, ports, shore-side authorities | The safety of new fuels may be an issue. Training and safety measures are required to minimize risks |
| Shipowners/operators | The shift to new technologies is capital intensive. There might be stranded assets due to the emergence of new technologies |
| Shipowners/operators and seafarers | The cost of reskilling and upskilling |
| Seafarers | Low-skilled seafarers would face employment challenges, but this also depends on the level of their skills. With the emergence of uncrewed, fully-autonomous ships (MASS), some seafarers may find work in Shore Control Centres (SCC) |
| Regulators and policymakers | There will be a need to formulate policies and amend existing laws and regulations to accommodate changes in conventions and codes |
| Shipowners/operators, developing countries | The range of technologies increase uncertainties. For example, the different future alternative fuels require different infrastructure. This is uncertainty about which option to invest in |
| Developed and least-developed countries | Connectivity divides as a result of technological and energy transition |
| States, shipowners/operators | Regulation most often tails behind technological development, which is why there is a need for goal-based regulations |
| Shippers and consignees | During the technological transition and market upheaval, costs will increase, creating negative impacts for Small Island Developing States (SIDS) and even developed and least-developed countries |

## 4.4 CONCLUDING REMARKS AND RECOMMENDATIONS: THE FUTURE SHIP

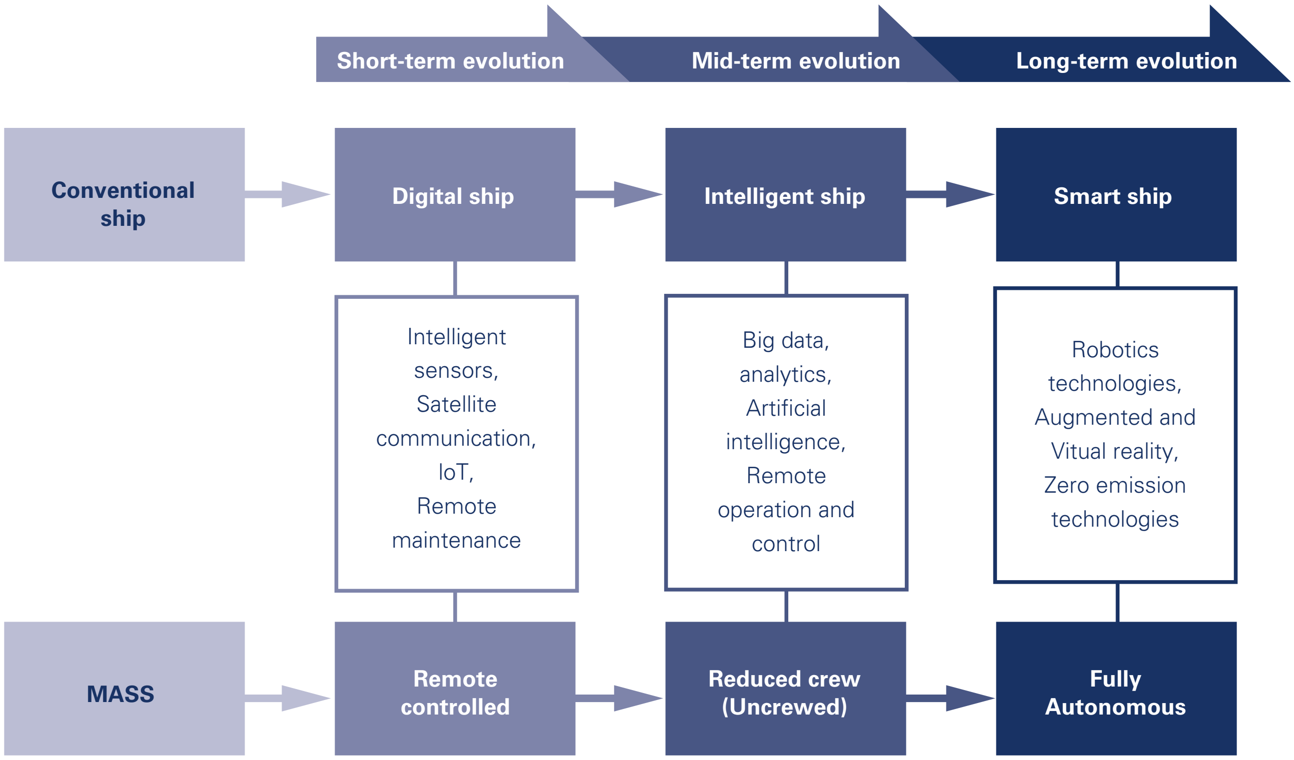
The maritime transport industry will continue to be the backbone of global trade, connecting people and commodities, while keeping the global economy alive and growing. However, the sector as a whole, including the maritime fleet, its infrastructure and operational systems, will inevitably undergo substantial transformation to integrate digitalization and automated technologies. However, this transition to smart and automated ships is expected to be gradual.

Future ships will be smarter and be facilitated by onboard wireless connections and digital connections via satellite and mobile communications. Integrated systems will be developed to provide shipowners and crew with information on operations and maintenance cost, the reliability and health of individual vessel as well as data on the logistics, life-cycle, energy consumption and emissions of a vessel, among many other aspects.[10] Smart ships will be facilitated by sensors and other technologies that generate relevant data for analytics to assist the Captain and crew with a variety of issues (e.g. weather routing, fuel consumption, virtual arrival, navigation, energy efficiency). Such future smart ships are termed "TechnoMax ship".[9]

The benefits of digitalization to shipping will include lower operational costs and greater energy efficiency, while also protecting the environment by using green power. In addition, ports will benefit from processing data to optimize arrival and departure procedures for vessels. Similarly, classification societies will be able to provide shipowners and operators with information on required maintenance and vessel health, thereby limiting downtime and maintenance costs.

The development towards fully autonomous shipping (MASS) will most certainly be evolutionary rather than revolutionary, as illustrated in Figure 2.11. Industrial outlooks in general are compatible with the research findings of this report (e.g. Lloyd's Register Global Marine Technology Trends including autonomous systems).[9,45] Figure 2.11 indicates that in the short to medium terms, ships will transition to becoming intelligent ships through the "exploitation of big data acquisition, communications and analytics to introduce intelligent, real-time and proactive decision making in the design, operation and maintenance of ships." In the medium to long-term, intelligent ships will become fully automated through the "exploitation of sensors and robotics technology to replace human operators, leading to semi-autonomous ships or fully-autonomous ships (i.e. remote controlled)." Even in today's conventional ships, uncrewed machinery spaces are a first step towards full autonomy since data-driven services are utilized to improve and optimize performance and recommend weather routing. It is worth noting that the path from digital and intelligent to smart ships intertwine with MASS evolution yielding ultimately greener and zero emission ships.

FIGURE 2.11 Future ship evolution




The technological developments studied in this report indicate that seafarers still have an important role to play in the evolution of the maritime industry. They will increasingly be supported by onshore specialists and experts. For the medium-term, seafarers will also remain indispensable on board. One of their key tasks today is to conduct regular maintenance and repair activities, such as replacing parts or lubricating moving parts while the ship is underway to avoid long downtimes at ports or dry docks.[18]

With future level-three and four of automation in MASS, some regular maintenance activities could be conducted from SCC enhanced by by simplified low lubrication and maintenance electric propulsion structure. However, periodic maintenance will be more challenging due to the complexities of systems that may not be compatible with conventional dry-docking services. This may require that maintenance and repair services are delivered by specific shipbuilders, dry docks and suppliers of autonomous ships technologies, necessitating MASS vessels to travel outside their regular zones of operation for periodic maintenance.[18] As a result, periodic and regular maintenance times and costs would increase, worsened by not-readily-available (or even verified) software engineering skills. A further barrier is the cost of configuration and repair of MASS-related technology (modular systems, redundant components, and backups systems, etc.). These maintenance and repair considerations may lead to reluctance among operators, owners and seafarers to adopt MASS technology.

Fully automated vessels are expected to be challenging to operate as such due to a lack of technological readiness among seafarers in addition to verification issues and other barriers.[18] The horizon for MASS shipping, including seagoing vessels facilitated by automated port loading and unloading, is 2050.[10] In the short-term, MASS operations will most likely be restricted to a lower level of autonomy due to the mentioned barriers. In the medium-term, existing technologies will develop and become mature through various testing and verification processes that support higher autonomy levels.[19]

While the feasibility of MASS shipping is still in question, it is nonetheless inevitable that the industry will face substantial transformation to integrate digitalization and incremental automation. The transition to MASS will not only be gradual, it may indeed not involve a binary scenario. We may, for instance, see the emergence of differentiated automation levels where uncrewed autonomous ships operate alongside crewed smart ships, in both cases benefitting from the digitalization and streamlining of their missions.[74] Arguably, MASS technology is most likely to first be adopted within Short Seal Shipping (SSS) due to this segment of shipping being heavily influenced by staffing and navigational costs and due to the simple management and routes predictability of this segment where its costal navigation would enable the utilization of terrestrial communications.[75–77] Several studies have addressed the likely application of MASS in SSS.[78,79] MASS may later expand to include large liners and ocean carriers, noting that a mix of crewed and uncrewed ships would be the first likely scenario.[18,49]

## 4.5 RECOMMENDATIONS FROM CHAPTER 2

Technological development is accelerating, offering the promise of industry-changing developments within the maritime transport sector, which is set to impact shipowners and seafarers alike.

There are over 50,000 ships in the global commercial fleet. They are registered in over 150 nations and crewed by nearly 2 million seafarers.[i] The Philippines, followed by the Russian Federation, Indonesia, China and India are the major suppliers of ratings and officers working on commercial ships.[j] Greece, China, Singapore and Hong Kong are the largest ship-owning nations. While half of the world's tonnage is owned by Asian companies, 40% and 6% of owners are from Europe and Northern America, respectively.[k]

This report has compiled a Technological Road Map for future shipping that covers the 10 main categories of technologies, including 26 sub-technologies. While these technologies offer operational efficiency benefits, they also present inherent opportunities to promote seafarer safety and wellbeing. ITF affiliates in general, and in particular those of the major seafaring and ship-owning nations, will benefit from adopting such technologies to enhance the safety, wellbeing, health and social improvement of seafarers. These opportunities are illustrated in the following individual recommendations:

### 1. Improvement of Seafarers' Infotainment and wellbeing

There is a link between social isolation and mental health issues of seafarers.[l] The wellbeing of seafarers will benefit from improving their communications and contact with relatives and friends. This can be achieved through adopting ICTs that enable infotainment (information and entertainment), offering reliable and affordable Internet access both at sea and during calls to port. Internet access is crucial to the morale of seafarers. Those enjoying Internet access are happier than those without access, according to the Seafarers Happiness Index.[m] Subsequently, the wellbeing of seafarers plays a significant role when choosing which shipping company to work for and it also boosts their job retention.

### 2. Support of Seafarer medical services at sea

Communication technologies can be a catalyst of greater seafarer health and better medical treatment. Shipping companies could offer an online health platform (telehealth service), which would reduce the current healthcare gap. This would allow seafarers on board to connect with healthcare practitioners or doctors on shore. Even basic Internet access would allow seafarers to communicate with medical services for guidance and instructions.

### 3. Improvement of online and virtual Seafarer training

Many competency certificates require physical attendance at training institutes. In addition, new technologies will increasingly require a wide scope of training options for seafarers by ship operators or managing companies in addition to training institutes. This report identified gaps in capacities and skills to operate new technologies in addition to other related competency issues. Information and communication technologies therefore promise to become game-changers in seafarer training and certification (i.e. via online training). Virtual and Augmented Reality (VR/AR) technologies could revolutionize training and education through virtual simulation.

### 4. Investigation of the bullying and harassment of seafarers

Physical bullying and harassment are issues that are mainly investigated in person with no technological intervention. Nevertheless, recent technology may support investigation

[i] 1,892,720 seafarers, of which 857,540 are officers and 1,035,180 are ratings

[j] https://www.ics-shipping.org/shipping-fact/shipping-and-world-trade-global-supply-and-demand-for-seafarers/

[k] UNCTAD e-handbook of statistics 2021

[l] https://thetius.com/how-can-technology-aid-seafarer-wellness/

[m] https://www.happyatsea.org/

and the collection of evidence, such as onboard cameras, motion and emotion sensors, computer-human interactions, BDA, and other data collection software.[n] Data analytics could most definitely help facilitate transparent investigation into issues such as harassment.

**5. Reduced administrative pressure on Seafarers**

Seafarers devote a lot of time to administrative duties. The automation of demanding processes would reduce paperwork and related work stress. Software As A Service (SaaS) could be used to manage seafarer credentials, which would facilitate communications between training providers and shipping companies. Seafarers could upload their credentials to storage (Cloud) and share them with prospective employers. Notifications could also be issued with information on expiry dates, training courses, employment opportunities and offers as well as application deadlines, etc. Blockchain technology could furthermore be utilized by training institutes to offer digital certifications and validations. The same could apply to the secure sharing of digital documents with employers, ships, port States, flag States, and other maritime authorities. Blockchains are already used by shipping companies, and the integration of digital certificates would simplify compliance and inspection, etc.

**6. Improvement of seafarer rest hours and wellbeing**

The manual registration of watch and rest hours is time-consuming. Using an automated watchkeeping registration software that acts as a virtual supervisor and records feedback from seafarers would simplify the procedure considerably. As an added benefit, watchkeeping schedules would become transparent and therefore more difficult to violate. Shore authorities would also become capacitated to examine ship compliance and share information with other relevant authorities to take specific action. Importantly, the integration of AI-assisted automated technologies would support seafarer wellbeing by minimising physical and mental work pressure through offering data-enabled support for decision-making.

**7. Improvement of the safety of seafarers and ships**

Ship operations mostly depend on decisions made by seafarers on watch, but humans make mistakes. The rise of AI-assisted technologies, such as autonomous navigation systems and artificial lookouts and engineers in addition to IoT, human augmentation and BDA, can all help improve the safety of ships and seafarers by minimising human error and the risk of accidents. These technologies support decision-making in complex situations and can warn crews of the risk of collisions or accidents in advance. Even workplace safety hazards could be addressed. The use of drones, robots and probes with fires, flooding and toxic leaks will minimize risks to seafarers, while maintaining ship safety.

**8. Technology should not have an adverse impact on seafarers**

While technology may aid seafarers in various aspects, it may also pose risks to their wellbeing, particularly concerning data privacy. While data is evidently essential for technological advancement and operational analytics, achieving a balance between information-sharing and privacy remains a challenge. Shipowners and seafaring nations must therefore ensure that seafarer data is secured and cannot be used against them. This will facilitate working with new technologies in human-technological interfaces and minimize concern among seafarers regarding the potential abuse of their data. Seafarers must feel confident that their personal data is protected.

**9. The technology Road Map benefits various maritime stakeholders**

The Technology Road Map offered in this report is designed to enhance knowledge among maritime decision and policymakers and strengthen their capability to identify future opportunities and risks. The aim is to enable shipowners, operators and shipping companies to make the right investment decisions at the right time, taking into account the different time horizons of the mapping. The current maritime fleet is notably getting older and its carbon emission are therefore also increasing (based on the UNCTAD review of maritime transport 2022),[o] which is why the technologies identified in the Technology Road Map are of particular relevance to investments in the coming years when the fleet undergoes renewal, which will see the advent of decarbonized, digital and smarter ships.

The Technological Road Map benefits maritime stakeholders by allowing them to identify long-term challenges and opportunities and thereby enabling them to prepare for the transition to new technologies in a timely manner, while addressing foreseeable barriers, such as the need for ports to improve their infrastructure and for METIs and shipping and managing companies to align their occupational training with current new technologies so seafarers are not left behind. In addition, shore authorities also need to develop relevant regulations and policies to facilitate shipping operations and technology adoption. Policymakers (national as well as international) must furthermore address the requirements of MASS technologies in current regulations. Guidelines need to be issued regarding HCI in ships to facilitate the interaction between humans (seafarers) and machines on different types of vessels or SCCs. Similarly, a framework would be required to minimize the risk of seafarer occupational redundancy in the light of the introduction of MASS. All stakeholders need to address the cybersecurity and data privacy issues in relation to the safety and security of ships and ports that arise as a result of digitalization.

[n] This would probably violate data privacy restrictions in e.g. the EU unless there is a case for criminal investigation. See recommendation 8 below and the chapter about the best practices in the Australian ship case study on data privacy issues

[o] https://unctad.org/meeting/launch-review-maritime-transport-2022

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CHAPTER 3

# FUTURE MARITIME SKILLS, COMPETENCIES, AND CAREER OPPORTUNITIES

3

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# 1 INTRODUCTION

It is evident that the maritime industry will be challenged by automation and technology advancement in the foreseeable future. Based on the technology roadmap presented in chapter 2, this chapter identifies how skills and competences of future seafarers may be affected by automation and technology.

Our primary study group for this report is seafarers. As technology advances, seafarer jobs may require reclassification in terms of the scope and nature of their duties as a result of task/function automation. Keeping the many uncertainties of technological advancement in mind, different scenarios for required seafarer skills have been developed to envision future new career and training opportunities. The methods applied in this chapter include integrating and triangulating results obtained during the previous project phase from relevant literature, secondary sources, expert workshops, large-scale surveys and qualitative and quantitative indicators. The aim was to help identify the skills training, upskilling and reskilling requirements that could effectively facilitate seafarer career transition in the maritime sector effected by increased digitalization, automation and decarbonization.

This chapter is organized in sections presenting: Trends in seafarer supply and demand; Skill gaps in the operation of smart & green ships; Automation in transition; Job opportunities for seafarers; and Lifelong learning in MET and seafarer careers; followed by the recommendations.

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# 2 TRENDS IN SEAFARER SUPPLY AND DEMAND

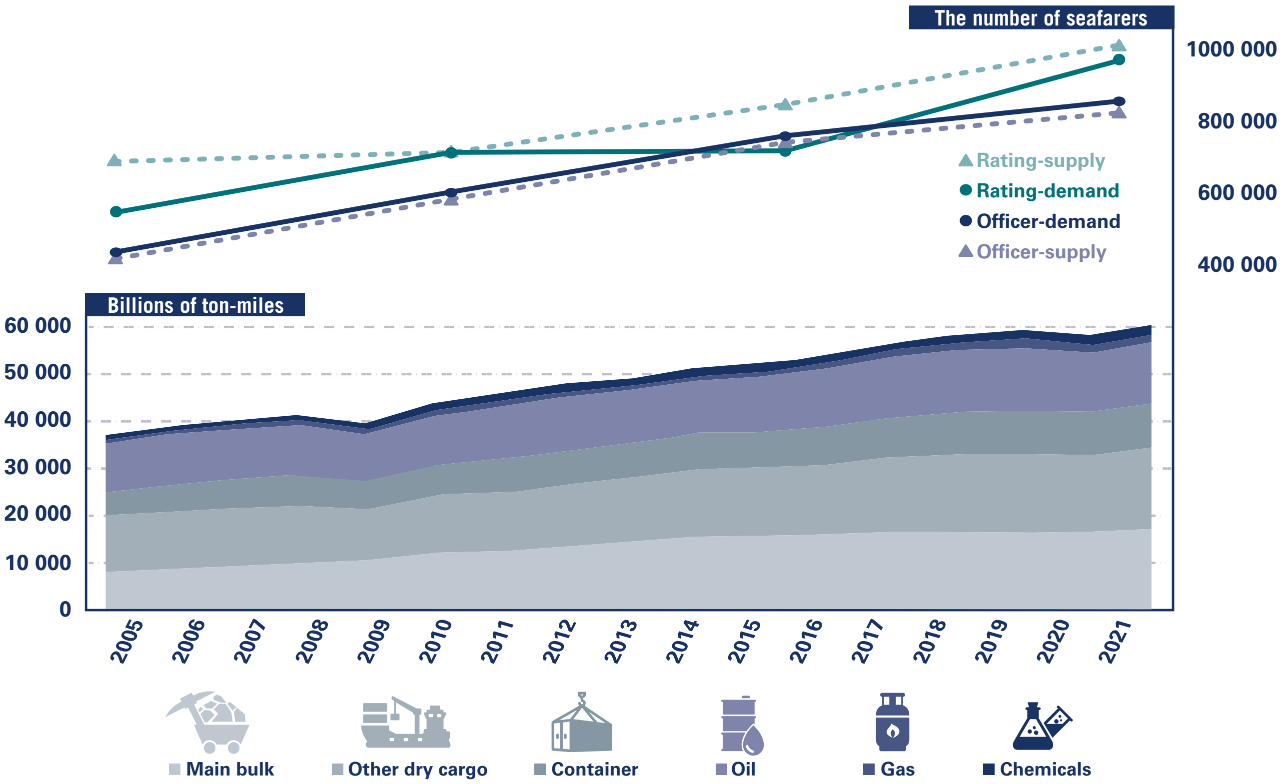
To facilitate our discussion on the future requirements for the skills and competences of seafarers, we open this chapter by benchmarking the current global supply and demand for seafarers in terms of demographic and logistical data, such as ship types, country of origin, age, and gender. A number of available reports and articles offer updated information on supply and demand trends for seafarers nationally and globally. The main source of our report has been the BIMCO and ICS workforce report, which we have triangulated with additional information, including reports from Drewry, EMSA, UNCTAD, and academic literature.

## 2.1 GENERAL TRENDS

Seafarer supply and demand is relative to the growth of the maritime trade. Figure 3.1 demonstrates how such market growth has increased between 2005 and 2021. Furthermore, data from UNCTAD[1] for world trade volume shows a corresponding increase by around 49% for the period from 2005 to 2020. According to the BIMCO and ICS report,[2] global demand in 2021 was approximately 1,881,320 seafarers, indicating an increase of 21.8% when compared to demand in 2005 (n=1,545,000). This trend is true for officers whose recruitment shortfall was estimated at 3.0% (n=26,240 minus) in 2021, while the over-supply of ratings reached 3.8% (n=37,640 plus) in the same year. Similar global trends for seafarer supply and demand in 2021 were observed in a study conducted by Drewry Maritime Research,[3] indicating an increase in officer supply by 0.9%, while demand for officers has risen by 2.4% with a subsequent officer shortfall estimated at around 20,500.

Forecasting the world fleet per sector from 2021 to 2026, the corresponding number of additional officers required to crew the vessels is estimated at: LNG (6.1%), Dry bulk (3.5%), LPG (2.4%), Oil tankers (1.7%), Chemicals (1.6%), Containers

FIGURE 3.1 Estimated global seafarer supply and demand and international maritime trade volume, 2005-2021



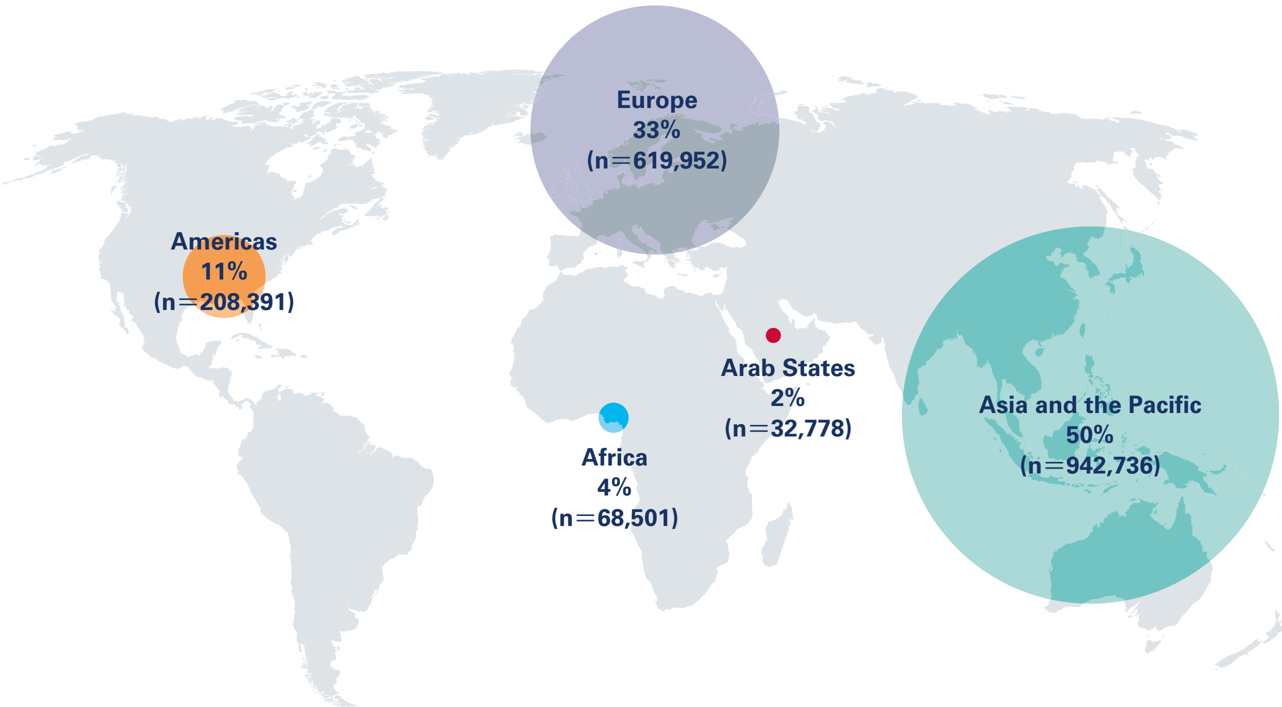

(Sources: UNCTAD analysis (2021, Fig.1.5), BIMCO/ICS (2021, Fig.4.16))

(0.8%) and Others (-0.2%). Overall, the global merchant fleet is expected to increase by 1.3% at a Compound Annual Growth Rate (CAGR), adding 3,100 vessels during the period. Projected fleet growth is expected to create demand for an additional 50,000 officers by 2026, whereas supply growth for ratings is expected to be 0.3%, a figure that remains in line with the rise in demand as the world fleet grows.[4] The supply of ratings is considered easier to manage than the supply of officers due to shorter training periods and lower entry requirements, allowing for a bigger pool of potential seafarers. Officers typically represent approximately 35-40% of the crew on board, which usually consists of an average of 23 crew members (e.g. 24-26 on VLCC, 20-24 on Panamax bulker, and 15-24 on LNG/LPG).[5]

## 2.2 REGIONAL PERSPECTIVE

The estimated total global supply of seafarers as of 2021 reached 1,872,358 with the majority (50%) of seafarers originating from Asia and the Pacific, followed by a third (33%) from Europe (Figure 3.2). Similarly, officers predominantly originate from these two same regions with 45% stemming from Asia and the Pacific, and 40% from Europe. More than half of ratings (55%) originate from Asia and the Pacific, while those from Europe make up over a quarter (27%). Seafarers from Europe totalled 339,121 officers and 280,831 ratings.[6] At European Union (EU) level in 2019, Captains and officers holding a valid certificate of competency (CoC) totalled 216,000 individuals as registered by individual EU Member States, including the United Kingdom (30,217),[a] Greece (21,850), Poland (20,829), Norway (18,793), and Croatia (14,962). Of which 3.55% are qualified to serve in both deck and engine departments. Ratings from the 16 EU Member States holding valid certificates of proficiency (CoP) in 2019 totalled 72,816 individuals with 6.24% entitled to serve in both the deck and engine departments.[7] Such certificate-holders could prove more resilient in the changing environment for work and career opportunities, which will be discussed in later sections of this chapter.

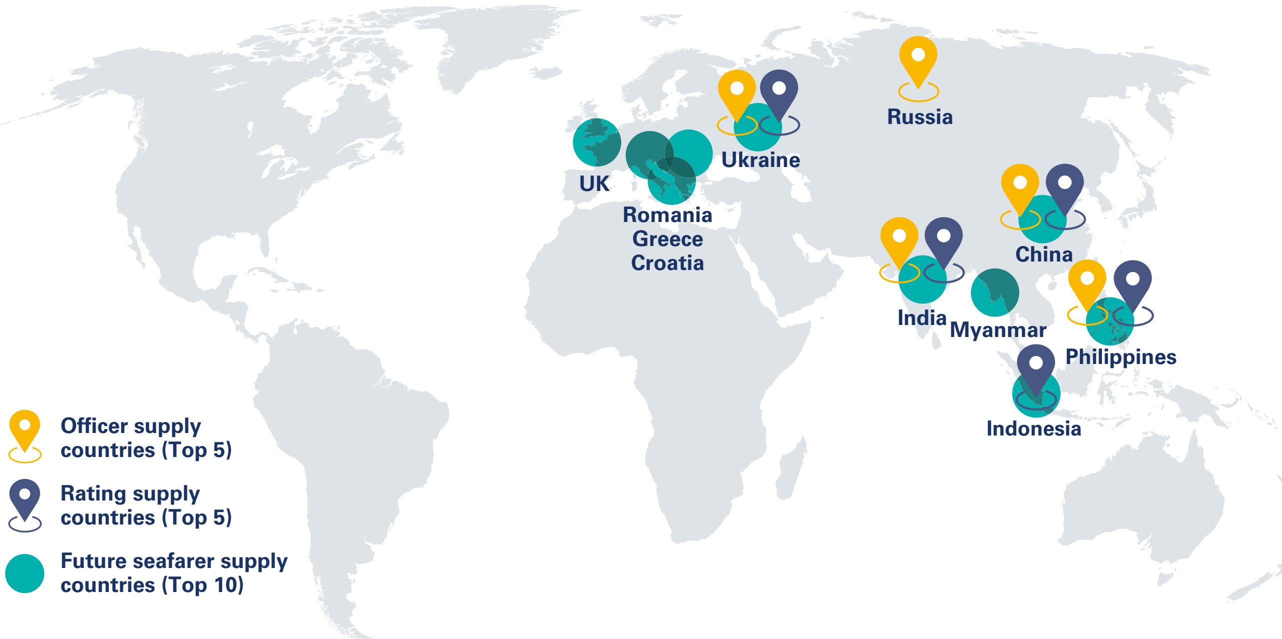
FIGURE 3.2 Estimated global seafarer supply share in 2021 by region




(Source: Adapted from BIMCO & ICS (2021))

[a] The EU data in 2019 was before Brexit and includes the UK as an EU Member State.

FIGURE 3.3 Top-5 seafarer supply countries in 2021 and Top-10 future seafarer supply countries selected by shipping companies




(Source: Adapted from BIMCO & ICS (2021))

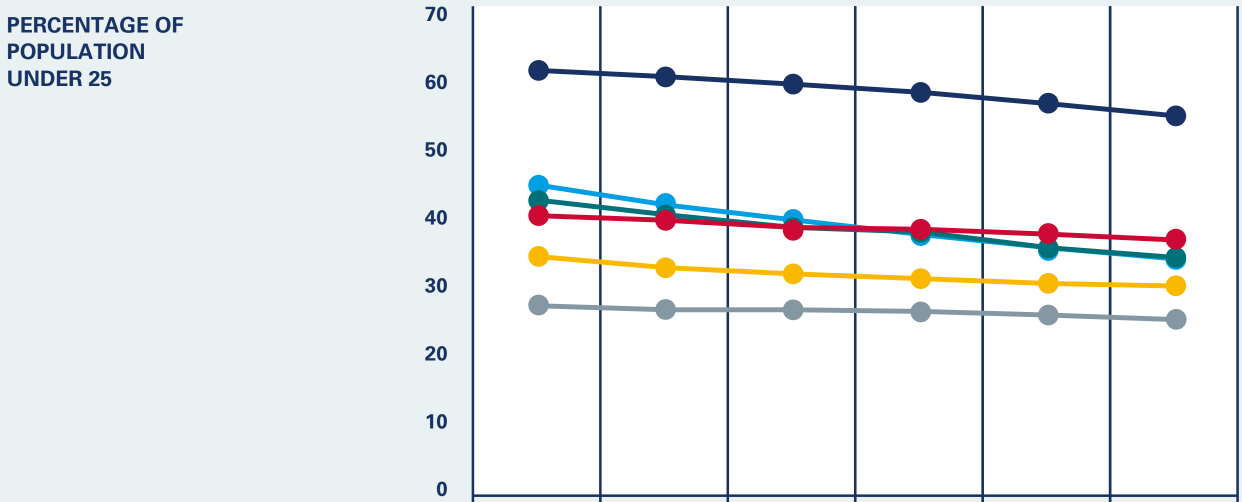
When studying seafarers by country of origin, shipping companies report employing officers from the Philippines, China, Ukraine, India, and Russia; and ratings from the Philippines, China, India, Ukraine, and Indonesia. Future seafarer supply countries are listed as Ukraine, Myanmar, Philippines, India, China, Romania, Greece, Indonesia, Croatia, and United Kingdom.[8] Figure 3.3 shows the distribution between seafarer supply countries that are expected to continue to crew conventional ships. However, the potential for seafarer supply appears to be underexplored in non-listed regions, such as Africa, the Americas, and Pacific/Oceania, which may see an advantage in quickly adapting to future changes and developing strategies to further supply seafarers.

## 2.3 AGE PERSPECTIVE

Despite the industry expecting greater future seafarer supply from Asia, Eastern Europe and Mediterranean countries, technology-proficient younger generations will possibly also be recruited from other regions. According to the World Population Prospects,[b] the world population under 25 years of age will decrease slightly by 2040 with the highest concentration of this age group living in Africa (53.8%), followed by Oceania (35.0%), Asia (32.6%), Latin America and the Caribbean (32.3%), Northern America (28.4%), and Europe (24.8%) (Figure 3.4). The Country Profiles in annex D additionally showed high scores in both the Technology and Innovation factor as well as the Economics and Business factor in Africa (e.g., South Africa), East Asia (e.g., South Korea) and Latin America (e.g. Chile). As the maritime industry embraces digitalization, the untapped human resources in Africa, Oceania, and Latin America and the Caribbean should therefore be considered for future maritime employment.

[b] Derived from the UN Department of Economic and Social Affairs, Population Division. https://population.un.org/wpp/Publications/

FIGURE 3.4 Population aged under 25 by region, 2015-2040



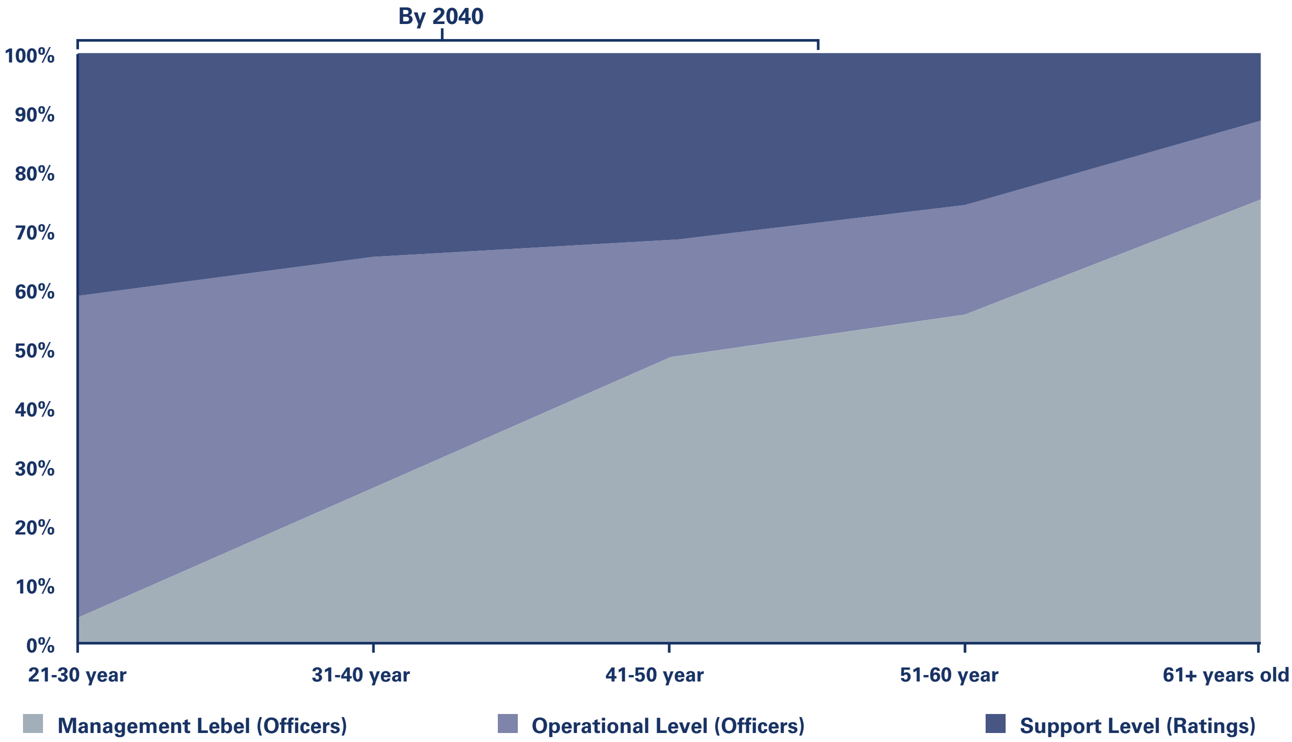

| | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|
| Africa | 60.5 | 59.6 | 58.5 | 57.2 | 55.6 | 53.8 |
| Asia | 40.9 | 38.8 | 37.1 | 35.6 | 34.0 | 32.6 |
| Europe | 26.9 | 26.3 | 26.2 | 26.0 | 25.4 | 24.8 |
| Latin America and the Caribbean | 43.2 | 40.3 | 38.0 | 35.9 | 34.1 | 32.3 |
| Northern America | 32.7 | 31.1 | 30.1 | 29.4 | 28.7 | 28.4 |
| Oceania | 38.7 | 37.9 | 37.3 | 36.7 | 35.8 | 35.0 |

(Source: WMU analysis based on United Nations, Department of Economic and Social Affairs, Population Division (2019). World Population Prospects 2019, custom data acquired via website.)

While the availability of younger generations globally indicates a recruitment potential for the maritime industry, Figure 3.5 provides insight into the current age profiles of seafarers at the management, operational and support levels, offering future scenarios for 2030 and 2040. The age profile of seafarers was sourced from the BIMCO and ICS 2021 report,[c] which indicates a shortage of officers and a surplus of ratings in the global seafarer workforce. Older age groups (41-61+ years old) tend to occupy the management level while most younger age groups (21-40 years old) are more likely to work at the operational or support levels. Forecasting the future by 2040, the current 21-40 year-old seafarers are expected to operate ships in the modern shipping environment. Should future seafarers be required to remotely manage ship operations ashore, the industry may face a shortage in supply of experienced seafarers at the management level. We will discuss the issue of where to recruit competent and skilled workers in section 6 of this chapter.

[c] Though it is not generalizable about seafarers' age profiles from the BIMCO and ICS survey and the demographic data varies significantly by country, this analysis aims to establish a discussion of how to attract young talents to source future maritime industries.

FIGURE 3.5 Age profiles of seafarers at management, operational, and support levels



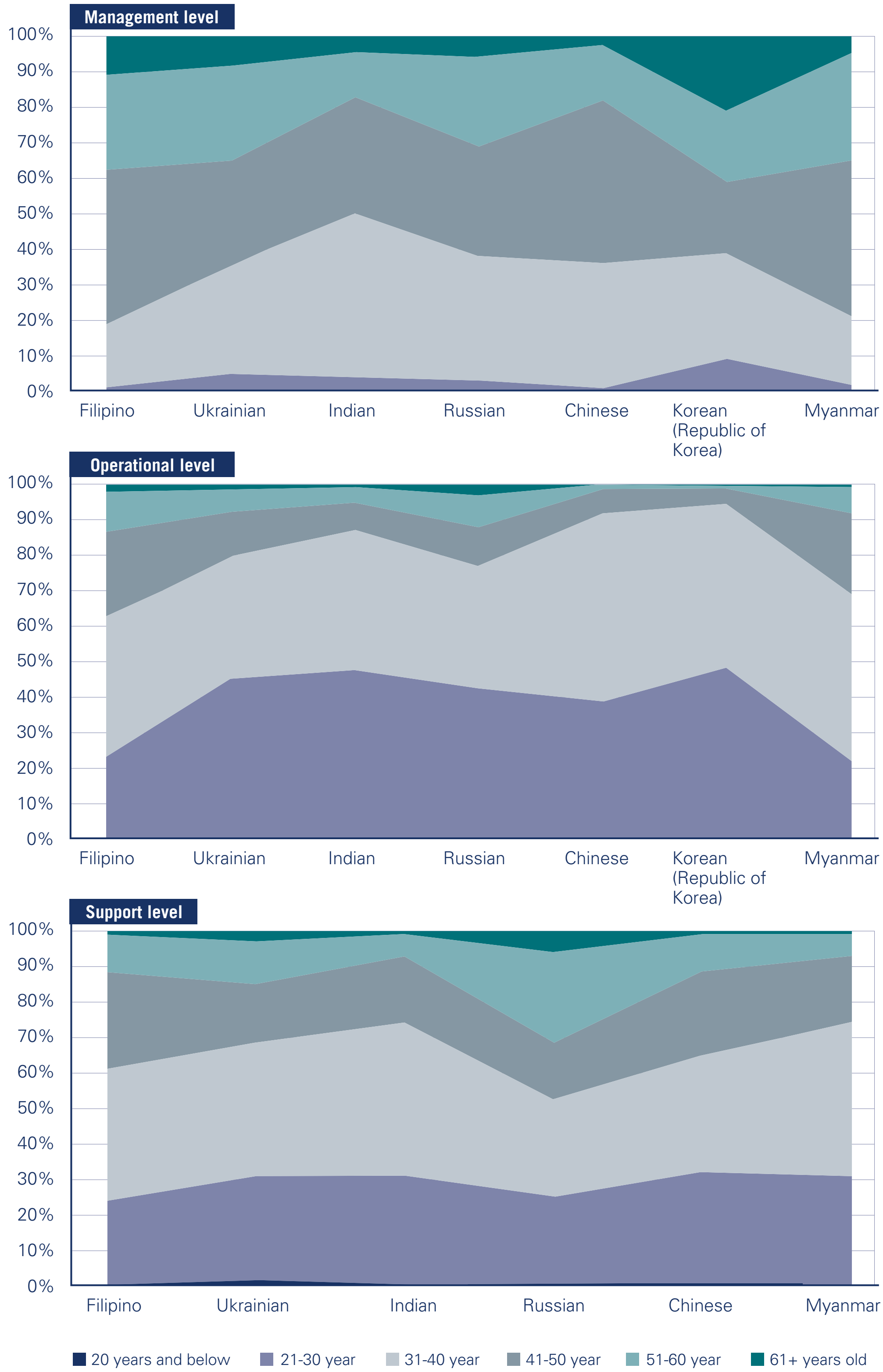

| Age group | Management Lebel (Officers) | Operational Level (Officers) | Support Level (Ratings) |
|---|---|---|---|
| 21-30 year | 3.1% | 35.1% | 26.8% |
| 31-40 year | 30.3% | 41.1% | 38.0% |
| 41-50 year | 37.4% | 15.3% | 24.0% |
| 51-60 year | 21.7% | 7.1% | 9.9% |
| 61+ years old | 7.5% | 1.3% | 1.1% |

Current / By 2030 / By 2040

(Sources: WMU analysis and BIMCO/ICS Seafarer Workforce Report 2021)

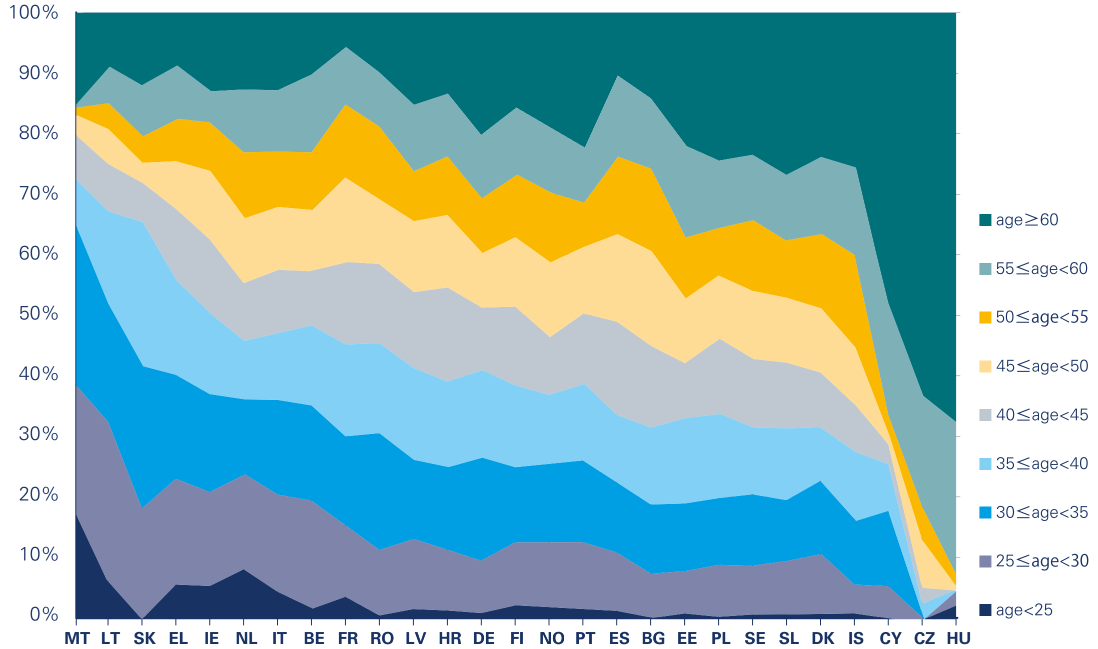
In addition to the global perspective, it is evident that this age distribution by level shows differences by country (Figure 3.6). While the 21-30 age group has a much lower representation than other age groups in selected seafarer supply countries, including China, India, Myanmar, Philippines, Russia, and Ukraine, Indian seafarers are comparatively younger than Chinese, Filipino, and Myanmar seafarers at management as well as operational levels (officers). Seafarers at support levels (ratings) in their 20s, 30s and 40s are currently in better supply on the global labour market. By 2040, when advanced automation and digitalization is foreseen in seafaring, the maritime industry is expected to face a challenge in securing young and talented seafarers.

FIGURE 3.6 Age profiles of seafarers at management, operational, and support levels by selected countries




(Source: WMU analysis and BIMCO/ICS Seafarer Workforce Report 2021)

FIGURE 3.7 Age profiles of Captains and officers in the EU and EFTA[d] in 2019




(Source: WMU analysis based on table 2-6 in the EMSA Report on Seafarers' Statistics in the EU, 2021. Note: Some EU Member States have very small numbers of Captains and officers, such as CZ, HU, IS, MT, SI, and SK. The data of some States from EU and EFTA are missing from the dataset.)

Similarly, from the EU perspective, younger generations have a lower representation than older ones across the EU. The age distribution of Captains and officers in the EU and European Free Trade Association (EFTA) in 2019 is presented in Figure 3.7. Among the States with more than 1,000 Captains and officers, Lithuania (LT), Greece (EL), Ireland (IE), Netherlands (NL), Italy (IT), and Belgium (BE) have a greater share of age groups under 30 compared to the other States. Cyprus (CY) shows the aging seafarer structure. Among 2,790 Captains and officers in Cyprus, the population share aged over 55 years is 69.2% while those under 30 years only represent 5.6%.

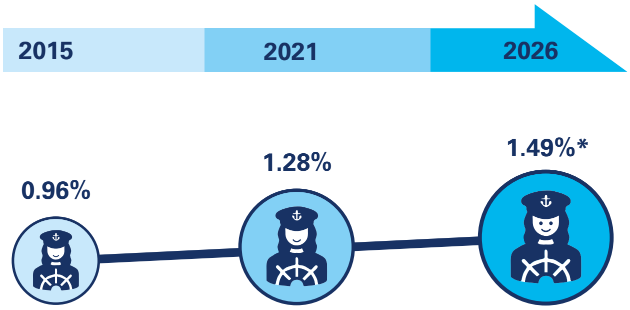
## 2.4 GENDER PERSPECTIVE

Similarly, another untapped human resource for the maritime industry is women. Based on reports by BIMCO and ICS published in 2016[9] and 2021, our projection for the global supply of women seafarers certified in Standards of Training, Certification and Watchkeeping (STCW) indicates different scenarios (Figure 3.8). In the event of Business as Usual (BAU), the estimated number of women seafarers in 2026 would be 7,435, representing 1.49% of the total STCW-certified seafarers worldwide. This slow progress in the employment of women seafarers observed in the last 30 years needs to be strategically actioned as soon as possible to build a sustainable, resilient, and forward-thinking maritime industry.

[d] The dataset includes the data from EU and EFTA, including Belgium (BE), Bulgaria (BG), Czechia (CZ), Denmark (DK), Germany (DE), Estonia (EE), Ireland (IE), Greece (EL), Spain (ES), France (FR), Croatia (HR), Italy (IT), Cyprus (CY), Latvia (LV), Lithuania (LT), Hungary (HU), Malta (MT), Netherlands (NL), Poland (PL), Portugal (PT), Romania (RO), Slovenia (SI), Slovakia (SK), Finland (FI), Sweden (SE), Iceland (IS), and Norway (NO).

As the overall demand for seafarers continues to rise, historical data indicates that upholding a balance between supply and demand is manageable provided training and recruitment growth is also maintained.[10] Considering that trends in seafarer supply and demand and in industry automation and digitalization are more evolutionary than revolutionary, the seafarer labour market is expected to weather potential disruptions fairly well and adapt to the required needs for reskilling and upskilling provided dedicated actions are taken in a timely manner.

FIGURE 3.8 Estimated supply of STCW-certified women seafarers between 2015 and 2026




*Estimated if 0.2% increase by 2026 is considered as BAU.
(Source: WMU analysis based on BIMCO & ICS (2016, 2021))

# 3 SKILL GAPS IN THE OPERATION OF SMART & GREEN SHIPS

The seafarer skills gap study investigated technical as well as soft skills. For benchmarking purposes prior to studying the future needs for seafarers, the current skills and competences of seafarers were derived from the STCW competence tables in addition to the European Skills, Competences, Qualifications and Occupations (ESCO)[e] and the Occupational Information Network (O*NET).[f] Surveys and expert workshops helped identify future skill gaps in relation to the operation of smart and green ships. This section presents our skills and skills gap analysis for the future.

## 3.1 SKILL FORESIGHTS

Academic literature and industrial reports generally apply terms such as hard/soft skills and technical/non-technical skills when categorising skills. Technical or hard skills are related to specific fields of work and associated with special tools, machineries, or equipment. The utilization of technical skills in technical procedures and practical tasks are observable and measurable. Technical skills can be acquired through academic paths, vocational and in-service courses, certification courses, and practical internships.[11] Soft or non-technical skills are commonly defined as "the cognitive, social and personal resource skills that complement technical skills and contribute to safe and efficient task performance".[12] Unlike technical skills, soft skills are generic and beyond the formal education syllabus. They do not belong to any specific job description or work environment, although they can be readily included in any job profile.[g] Soft skills cannot be acquired overnight, but they can be cultivated with practice and extensive experience. These two sets of skills – technical and soft skills – do not function separately or in competition, but rather complement each other.[13] Accordingly, the required skills for seafarers in this study are clustered into the two major categories of technical skills and soft skills.

Our analysis demonstrates that technological advancement does not seem to require drastic changes in soft skills. The managerial responsibilities of Captains and Chief Engineers will remain equally important in the future and will not differ considerably from those of their current peers. Crew members are expected to possess the same soft skills, such as self-management, intellection, core literacy, and resource management. However, when it comes to communication skills, seafarers may need to adapt to future advanced means and tools of communication. Nevertheless, their current knowledge in communication will remain relevant, such as: why, what, how, when, and to whom they should communicate.

The technological development is expected to cause the technical skills gap of seafarers to widen considerably in comparison to their soft skills gap (Figure 3.9). While revolutionary changes in the requirements for technical skills can be expected in the mid to long-term, soft skills will mainly experience evolutionary change. These developments will create skill gaps in relation to STCW requirements. The next major revision of the STCW Convention and Code will take time to adopt and implement, which is predicted to occur in the long-term (2031-2040).

The technical duties of seafarers have historically undergone change in step with technological advances, such as with the introduction of the Electronic Chart Display and Information System (ECDIS) that replaced chart papers. Other examples include the remote-control system for valves – a development that has been effective in reducing the need for engineers to operate valves manually – and the Boiler Management System (BMS), which has made boiler operation fully automatic. The race to adapt to technological progress has caused maritime administrations, industry and Maritime Education and Training Institutions (METIs) to collaboratively responded by providing new regulations and guidelines, standardized products, and necessary training. Figure 3.9 demonstrates how new skills have been added to facilitate the operation of mature technologies, a process in which METIs have succeeded in adapting their syllabus to meet industry needs.

In the short-term (2022-2026), digitalization will increase in Research and Development (R&D) related to maritime operations, although many new technologies involved in industry R&D will be test cases and immature as standard products. Regarding seafarer skills during the same period, the Comprehensive Review of the STCW Convention and Code will be ongoing and undertaken by the Human Element, Training and Watchkeeping (HTW) Sub-Committee of IMO. Since the requirement for seafarer skills as specified in STCW

[e] Further information on ESCO (European Skills, Competences, Qualifications and Occupations) can be found in European Commission website, https://esco.ec.europa.eu/en

[f] Further information about the Occupational Information Network (O*NET) and corresponding data can be found at https://www.onetcenter.org/database.html#overview

[g] Some soft skills may be called "meta skills" but in this report, we use the terms, technical and soft skills.

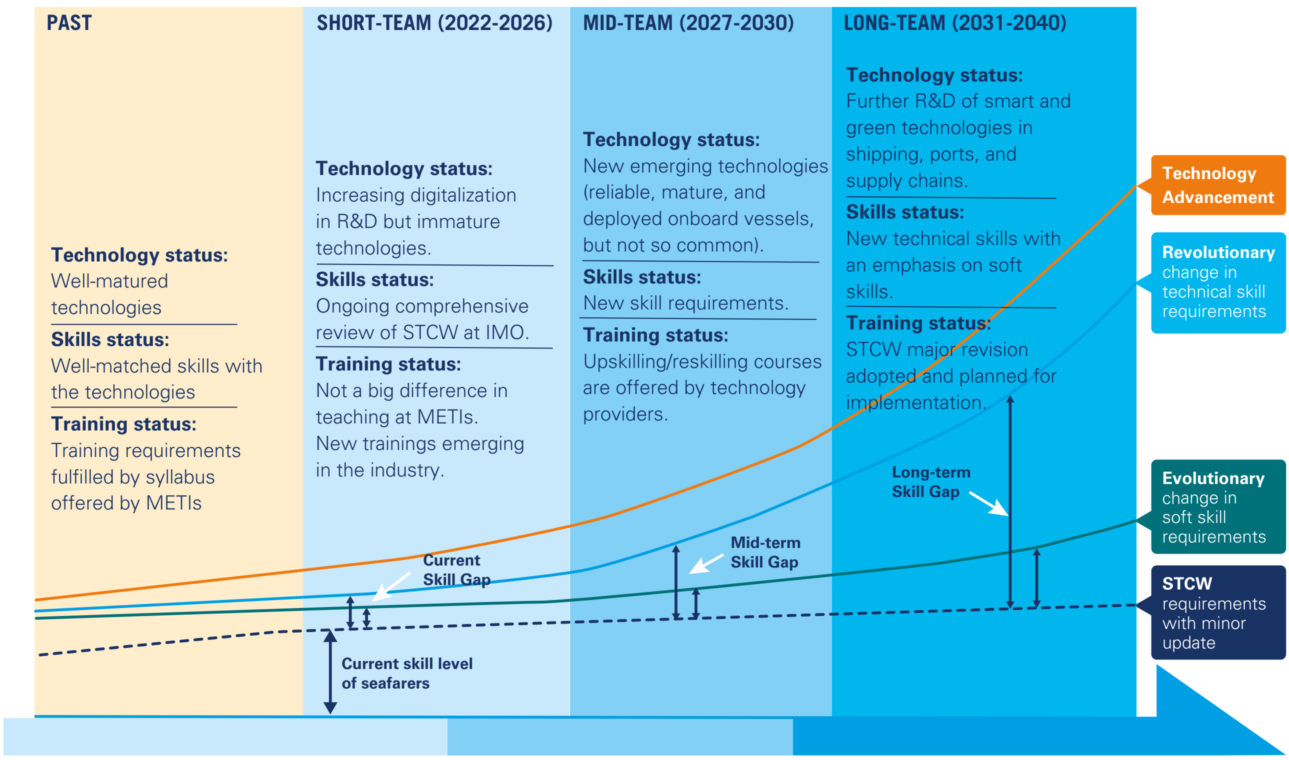
is expected to remain the same, there will be no significant changes involved in the training of seafarers at METIs. However, manufacturers and software companies have already started providing seafarer upskilling, which targets specific technologies deployed on newer vessels.

In the medium-term (2027-2030), some vessels will deploy new emerging technologies that are relatively reliable and mature, although not widely adopted by the global fleet. Such medium-term technologies will include electrified propulsion, LNG-fuelled engines and Integrated Bridge Systems (IBS). Accordingly, new skills will be required to operate these shipborne technologies, and the relevant upskilling and reskilling of seafarers will be offered by technology providers.

In the long-term (2031-2040), further R&D is expected within smart and green technologies in shipping, ports, and supply chains, which will give rise to new jobs and careers. This will lead to requirements for new technical qualifications with an emphasis on soft skills. The standards for seafarer competences will furthermore be updated through the major STCW revision, which is to be adopted and planned for implementation. Accordingly, METIs should update their curriculum regarding seafarer training under the revised STCW.

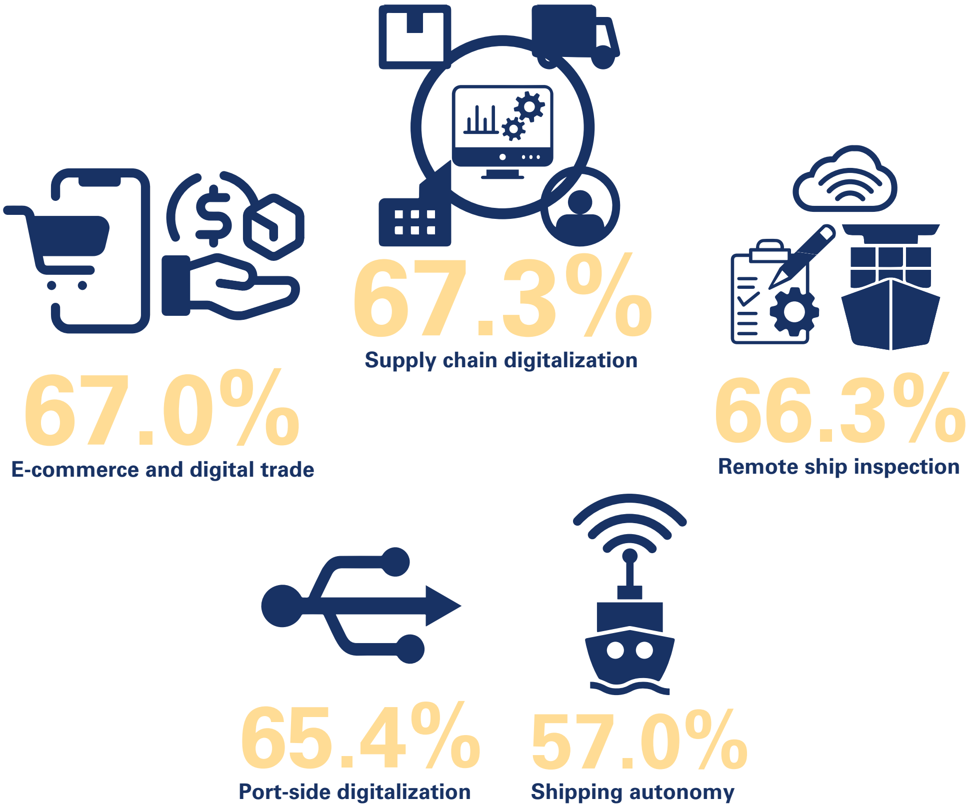
As the arrows in Figure 3.9 indicate, the skill gaps of seafarers correspond to the technology gaps between modern and conventional ships. Ships will continue to respond to various needs in different parts of the world, which is why STCW-certified seafarers will also continue to find onboard employment, although upskilling will be required to operate newly deployed technologies and ensure a smooth transition.

FIGURE 3.9 Technology advancement and skill/training requirements over time




Predicting future requirements for technical skills is challenging since technology advancement is heavily influenced by a wide range of external factors, including economic, geopolitical, and regulatory factors in addition to many trends discussed in chapter 2. For instance, the COVID-19 pandemic at its peak led to a sharp decline in fuel prices, which delayed energy efficiency projects in shipping, while promoting digitalization. Figure 3.10 illustrates the top-5 responses from our survey on how the COVID-19 pandemic affected the advancement of digital technology in the maritime industry: Supply chain digitalization; E-commerce and digital trade; Remote ship inspection; Port-side digitalization; and Shipping autonomy.

FIGURE 3.10 Impact of COVID-19 in technology advancement




(source: FOMJ survey)

Technology can be advanced by unforeseen events, such as COVID-19, which makes it difficult to predict how the requirement for specific skills may evolve over time. Considering the time scope of 2040, the skills gap analysis in this project has been divided into three phases: short, mid and long-term. The short-term skills gap analysis is based on a detailed review of the Knowledge, Understanding, and Profession (KUPs) and competencies required by the STCW Convention. For the medium-term, an online study was conducted of the official websites of pioneering technology providers within the maritime industry. Their training courses offer insight into the scope of new seafarer skills required to operate advanced new technologies. Furthermore, the technology roadmap presented in chapter 2 highlights the future technology trends, offering overall insight into the related skills required in the long-term.

### 3.1.1 SHORT-TERM SKILL REQUIREMENTS: STCW GAP ANALYSIS

An STCW gap analysis has been conducted to identify the short-term skills requirements for seafarers. In this context, STCW Code Part A and B as well as various models of training courses were investigated, including 7.01,[14] 7.02,[15] 7.03,[16] 7.04[17] and 7.08.[18] For decades, the STCW Convention has been the reference standard for Maritime Education and Training (MET) and seafarer certifications, highlighting the required qualifications and KUPs of seafarers at the management, operational and supportive levels. In addition to defining such competences, STCW also determines the methodologies and criteria by which relevant competencies are identified. Supported by the WMU analysis and workshops, the following skill gaps were identified in the current STCW requirements:

#### Administrative skills

Administrative skills, including reporting and documenting knowhow, have been given less emphasis in the STCW Code. Crew members on management and operational levels as well as steward staff must possess administrative skills[19,20] that comply with the various reporting and documentation formats required by port authorities, shipping companies, and third parties, such as agents and classification societies.

#### Communication skills

A radio communication function as defined by STCW gives emphasis to the required competencies for GMDSS radio operation. However, a broader sense of communication[21,22] skills needs to be strengthened, including ship-to-ship,

ship-to-port, ship-to-company, ship-to-third party and shipboard communication.

**Skills to prepare ship for inspections**

Ship inspections with different objectives, such as port/flag state inspections, vetting inspections, internal/external audits, voluntary inspections (e.g. ISO and Green Award), and class surveys, require a thorough understanding of the nature, timing, scope, and objectives of each inspection as well as possessing the skills to execute them consistently. The current STCW Code gives less importance to this knowledge and these skills.

**Skills to respond to emergencies**

Emergency scenarios are diverse in the modern world. The current STCW Code lists emergency eventualities and specifies the role distribution in such cases among different shipboard ranks and functions. As a result, some emergency situations have been overlooked and relevant skills have therefore not been assigned. Examples include onboard blackouts, ship recovery from engine failure, oil spills, and enclosed space rescue. In the event of navigational emergencies, for instance with ship grounding, engineers must check the condition of the propulsion engine as well as the double-bottom hull structure. However, no KUPs are assigned to engineers. The synergy between deck and engine departments plays a crucial role in contingency management.[23] A comprehensive list of emergency scenarios should additionally include newer risks related to cyber security as well as new machineries/systems.

**Digital and ICT skills**

With the rapid development of modern information and communication technologies, the maritime industry is keen to increase the use of ICT applications in various functions onboard vessels.[24,25,26] The current STCW, however, does not refer to ICT skills for deck and engineer officers.

**Skills to maintain cyber security**

With the constant increase of volume and speed of data being exchanged between ships, ports, shipping companies and third parties, IMO has received reports on the risks related to cyberattacks on ships and shipping companies. The COVID-19 pandemic demonstrated a necessity to move further towards digitalization to improve the resilience of the shipping industry. This development, however, requires an understanding of cyber security among seafarers and port operators.[27] No skills related to cyber security are included in the STCW or in KUPs related to ISPS.

**Skills in commissioning new machinery**

Technology advancement has increased the need for commissioning of new machinery for new as well as retrofitted ships. This requires seafarers to gain a thorough understanding of the clauses of all warranties and insurance contracts related to newly installed machinery. There is no reference to any of such training in KUPs in the STCW Code.

**Environmental awareness and relevant skills**

The STCW Convention covers safety-related codes, conventions, procedures, and equipment.[28,29] However, with regard to environmental aspects, the convention only refers to the term "protection of the marine environment" without any explicit clarification in terms of environmental conventions, machinery, inspections, and procedures. Indeed, the majority of amendments to the STCW Code result from proposals made at IMO Maritime Safety Committee (MSC) meetings.

### 3.1.2 MEDIUM-TERM SKILLS REQUIREMENTS

Skills requirements in a medium-term perspective mainly pertain to the upskilling offered by maritime technology providers supplying the latest operational software to shipping companies. These training courses are provided by such pioneering technology providers in the maritime industry as ABB, WÄRTSILÄ, Kongsberg, Rolls-Royce, SIEMENS, Yara Marine, and Alfa Laval (see annex B). A list of operational software systems and the providing companies is presented in annex C. The abstracted list of medium-term skills is presented in the middle block of Table 3.A.

## TABLE 3.A Future skills by shipboard job

| SKILLS | | SHIPBOARD JOB TITLES | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | MANAGE. LEVEL | | OPERATION LEVEL | | | SUPPORT LEVEL | | |
| | | Master/ Chief Off. | Chief/2nd Eng. | Deck Off. | Eng. Off. | Elec. Tech. Off. | Deck Rating | Engine Rating | Steward Staff |
| **SHORT-TERM[1]** | Administrative skills | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ |
| | Communication skills | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Skills to conduct vessel inspections | ✓ | ✓ | ✓ | ✓ | ✓ | | | |
| | Skills to respond to emergencies | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Digital and ICT skills | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Skills to maintain cyber security | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Skills for machinery commissioning | ✓ | ✓ | ✓ | ✓ | ✓ | | | |
| | Environmental awareness and relevant skills | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **MID-TERM[2]** | **Skills to operate/maintain:** Hybrid propulsion system (e.g. Diesel-Electric) | | ✓ | | ✓ | ✓ | | ✓ | |
| | Pod propulsion system | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Nox reduction equipment | | ✓ | | ✓ | ✓ | | ✓ | |
| | Sox scrubbers | | ✓ | | ✓ | ✓ | | ✓ | |
| | Ballast Treatment plants | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Dual Fuel engine technology | | ✓ | | ✓ | ✓ | | ✓ | |
| | LNG handling system (bunkering, storage, and usage) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Advanced electrical systems (e.g. Cycloconverter, frequency converters, and Variable Speed Drives) | | ✓ | | ✓ | ✓ | | | |
| | Advanced automation/control systems | ✓ | ✓ | ✓ | ✓ | ✓ | | | |
| | Advanced alarm and monitoring systems in E/R | | ✓ | | ✓ | ✓ | | | |
| | Advanced alarm and monitoring systems in bridge | ✓ | | ✓ | | | ✓ | | |
| | Ship operational software | ✓ | ✓ | ✓ | ✓ | ✓ | | | |
| **LONG-TERM[3]** | **Skills/ knowledge/ competence to:** Operate/maintain Real-time Monitoring system | ✓ | ✓ | ✓ | ✓ | ✓ | | | |
| | Handle alternative fuels | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Work in shore control centers | ✓ | ✓ | ✓ | ✓ | ✓ | | | |
| | Operate technical energy efficiency measures | ✓ | ✓ | ✓ | ✓ | ✓ | | | |
| | Maintain/operate the wind-assisted technologies | ✓ | ✓ | ✓ | ✓ | ✓ | | | |
| | Maintain/operate the advanced/ electrified propulsion systems | ✓ | ✓ | ✓ | ✓ | ✓ | | | |
| | Maintain/operate the pollution/emission prevention technologies | | ✓ | | ✓ | ✓ | | ✓ | |
| | Handle advanced navigational equipment | ✓ | | ✓ | | | ✓ | | |

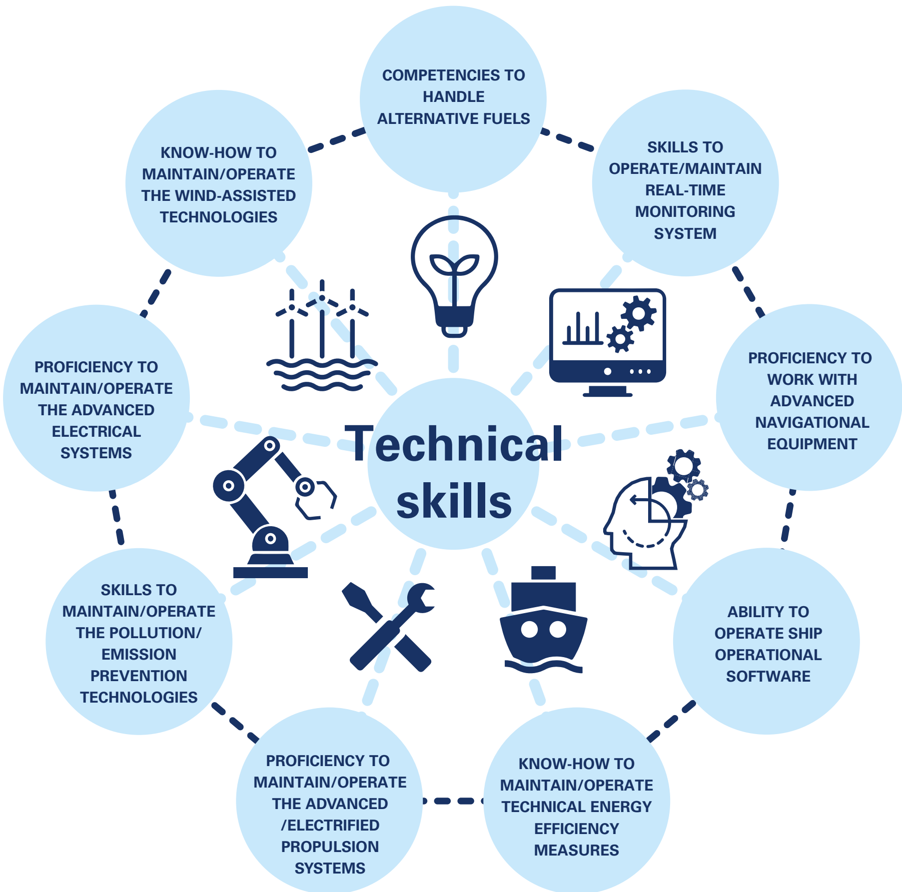
([1] Results of STCW skill gap analysis; [2] Results of a review on training courses offered by technology/ software providers; and [3] Consolidated results of surveys, workshops and focus groups)

### 3.1.3 LONG-TERM SKILLS REQUIREMENTS

The WMU analysis on long-term skills was based on primary data (surveys, workshops, and technology road map from chapter 2) and secondary data (academic literature, industry standards and reports). Figure 3.11 offers a projection of the future technical skills required for seafarers within the horizon of 2040.

Regardless of the time horizons for future skills in general, soft skills will remain essential when developing technical skills. In ship operation, seafarers always need soft skills. A major reference when developing the list of necessary soft skills (Figure 3.12) was the WEF report[30] that was used for the WMU analysis of surveys and workshops in which shore-based managers ranked the importance of each skill. .

FIGURE 3.11 An outlook of technical skills required by seafarers in the long term



## 3.2 SKILLS GAP ANALYSIS

Skills workshops were held to identify the future skill gaps of seafarers based on a listing of technical and soft skills. In each workshop, participants were asked to rank the importance of enumerated skills on a scale from one to five both in the present and future, considering a 2040 horizon. The magnitude of each skills gap was determined by the differences in current and future ranking. The results of the gaps analysis for technical and soft skills are summarised in Table 3.B.

The major gaps in technical skills were identified in relation to unconventional and immature technologies, such as alternative fuels, advanced electrified propulsion systems, electrical systems, and wind-assisted technologies. These technologies are less common in the global fleet and therefore represent a wider skills gap since seafarers have yet to be exposed to them. Indeed, only a minor skills gap was registered in relation to current technologies that seafarers are familiar with. This included pollution/emission abatement technologies (e.g. $SO_x$ scrubber and MARPOL machinery) and operational software (e.g. weather routing and trim optimization).

FIGURE 3.12 An outlook of soft skills required by seafarers in the short, mid and long terms

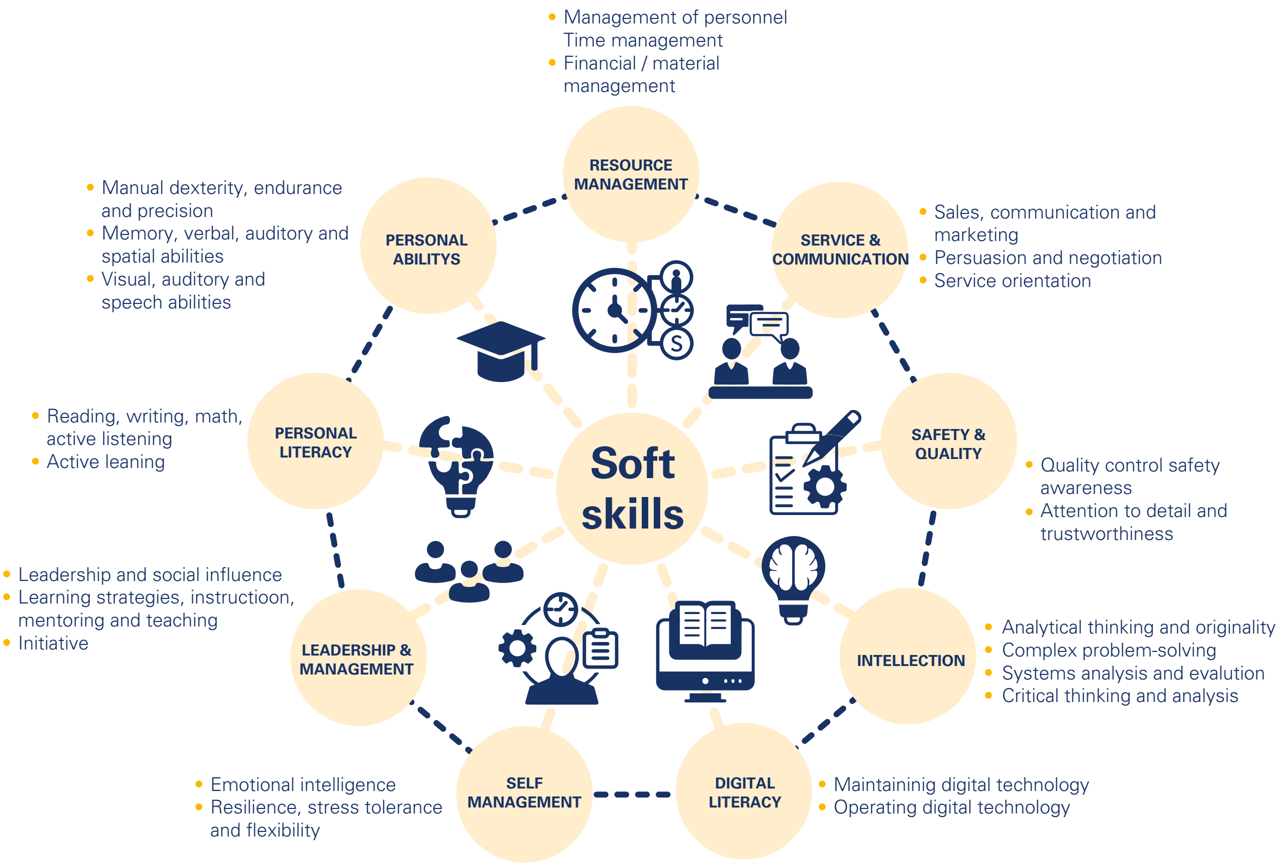


TABLE 3.B Seafarer skill gaps

| | | MAJOR GAP | MODERATE GAP | MINOR GAP |
|---|---|---|---|---|
| **TECHNICAL SKILLS** | Competencies to handle alternative fuels | ✓ | | |
| | Proficiency to maintain/operate the advanced /electrified propulsion systems | ✓ | | |
| | Proficiency to maintain/operate the advanced electrical systems | ✓ | | |
| | Know-how to maintain/operate the wind-assisted technologies | ✓ | | |
| | Know-how to maintain/operate technical energy efficiency measures | | ✓ | |
| | Skills to operate/maintain Real-time Monitoring System | | ✓ | |
| | Proficiency to work with advanced navigational equipment | | ✓ | |
| | Ability to operate ship operational software | | | ✓ |
| | Skills to maintain/operate the pollution/emission prevention technologies | | | ✓ |
| **SOFT SKILLS** | Maintaining digital technology | ✓ | | |
| | Systems analysis and evaluation | ✓ | | |
| | Using and operating digital technology | ✓ | | |
| | Analytical thinking and originality | | ✓ | |
| | Active learning | | ✓ | |
| | Learning strategies, instruction, mentoring and teaching | | ✓ | |
| | Sales, communication and marketing of products and services | | ✓ | |
| | Critical thinking and analysis | | ✓ | |
| | Complex problem-solving | | ✓ | |
| | Attention to detail, trustworthiness | | | ✓ |
| | Initiative | | | ✓ |
| | Resilience, stress tolerance and flexibility | | | ✓ |
| | Core literacies: Reading, writing, math, active listening | | | ✓ |
| | Management of personnel | | | ✓ |
| | Service orientation | | | ✓ |
| | Persuasion and negotiation | | | ✓ |
| | Quality control and safety awareness | | | ✓ |
| | Management of financial and material resources | | | ✓ |
| | Leadership and social influence | | | ✓ |
| | Memory, verbal, auditory and spatial abilities | | | ✓ |
| | Emotional intelligence | | | ✓ |
| | Visual, auditory and speech abilities | | | ✓ |
| | Coordination and time management | | | ✓ |
| | Manual dexterity, endurance and precision | | | ✓ |

Our study confirms the supportive role of soft skills in enhancing technical skills. In addition, soft skills are recognized as having greater importance than technical skills. Nonetheless, the human element, including the development of soft skills, has been neglected in maritime training where, furthermore, such training is only partially mandatory.[h] STCW sets out guidelines for crisis management and human behaviour training, yet does not deal with the major gaps in soft skills that pertain to the operation and maintenance of digital technology or systems analysis and evaluation. At the time when the STCW Convention was originally adopted, soft skills were traditionally considered part of "seamanship," i.e. a general concept of attitudinal qualities embedded in traditional sailing ship cultures where veterans and novices would closely interact to transfer knowledge and skills. The lack of discernible behavioural criteria to assess and benchmark soft skills could arguably be one of the most persistent barriers to the wider integration of soft skills into general competency requirements. STCW, for instance, employs the generic term of "performance output," which opens the door to diverse interpretations.

Each workshop concluded with participants discussing the validity of the identified skill gaps and proposing possible approaches the shipping industry could adopt to bridge these skill gaps. When reviewing the required technical skills for seafarers, it is evident that the primary concerns of the standards were safety and the environmental aspects of ship operation. Indeed, the maritime industry is increasingly expected to deploy advanced technologies in addressing such long-standing issues as marine accidents and climate change. In this context, Table 3.C lists the top-5 most important technical and soft skills for future seafarers as ranked by respondent employers in the survey.

TABLE 3.C Top-5 rankings of technical and soft skills based on their importance in the future

| TOP-5 SOFT SKILLS | TOP-5 TECHNICAL SKILLS |
|---|---|
| S1. Quality control and safety awareness | T1. Competencies to handle alternative fuels |
| S2. Resilience, stress tolerance and flexibility | T2. Skills to operate/maintain Real-time Monitoring System |
| S3. Management of personnel | T3. Proficiency in working with advanced navigational equipment |
| S4. Using and operating digital technology | T4. Ability to operate ship operational software |
| S5. Active learning | T5. Know-how to maintain/operate technical energy efficiency measures |

(source: FOMJ survey)

Future skills for seafarers are not only technology-related but also soft skills, including interpersonal, managerial and creative skills.[31] Overall, the top-5 technical and soft skills in Table 3.C reflect such skills prioritized in other recent studies, including the ICS study on seafarers and digital disruption conducted by the Hamburg School of Business Administration,[32] Fair future for seafarers study by Thetius-Inmarsat,[33] Technology in shipping report by the Clyde & Co and IMarEST joint initiative,[34] and many others.[35] These studies focus on how automation and digital technologies effect the changing role of seafarers in the maritime industry, particularly within the aspects of autonomous/smart shipping, alternative energy and green technologies.

According to the experts attending the skills workshops, seafarer soft skills will undergo incremental change as they adapt to more tasks being executed by technology. The experts placed great emphasis on cooperation and communication skills and noted that improved onboard and onshore communication skills may even result in the reform some managerial duties. For instance, many decision-making tasks (e.g. ship speed and routing) could in the future be transferred to shore management. Inventory lists could also be ordered through ship chandlers directly by Captains using advanced communication channels. Improved communications skills among stakeholders could indeed benefit the entire supply chain of the shipping business, which would lead to a demand for other new soft skills.

Automation and digital technologies represent a new wave of opportunities and challenges for the maritime industry. As addressed by the previous reports of the Transport 2040 project, maritime workers, including seafarers, should benefit from the advantages of technology. Our study indicates that there is a general consensus on the manageability of the risks posed by automation, digitalization and corollary technological developments, but that such management would require dedicated action. Given the nature of technology and the required skills of operation, the responsibility for successful implementation evidently rests not only on seafarers but also on all other stakeholders involved in maritime and allied industries.

[h] STCW Code includes mandatory requirements on leadership, assertiveness, teamworking, and effective communication as limited examples of soft skills.

# 4 AUTOMATION IN TRANSITION

Various ship operation functions have been partly automated.[36] Automated Boiler Controls (ABC) were introduced in post-war United States in 1964 to enable boiler operation without constant human attendance.[37] Autopilot was one of the earliest automation technologies installed on navigational bridges. Automatic Radar Plotting Aids (ARPA) were introduced to support overall collision avoidance by automatically tracking targets. The digitalization of sea charts (e.g., ENC, ECDIS) also aided manual watch-keeping, routing and cross-checking. The automation in engine-rooms is another example of partial automation on board ships.

Seafarers undertake a variety of duties under their designated roles as Captains, Chief Engineers, senior and junior officers, and ratings. Such seafarer tasks may in the future be partially automated. A pathway towards an autonomous maritime future involves a process of adapting to digitalization similar to the process undertaken with partial automation, yet at a more accelerated pace. The automation of most vessels in operation can therefore reasonably be considered as a step-by-step process rather than a wholescale transformation towards ultimate uncrewed ships. Ship operation tasks that can technically be automated include decision-support systems for manoeuvring, berthing and docking.[38]

This section demonstrates how the transition towards automation may affect onboard systems as well as how task automation and function automation may impact the workplace of a seafarer from a human factors perspective. It also considers how new work values may be shaped.

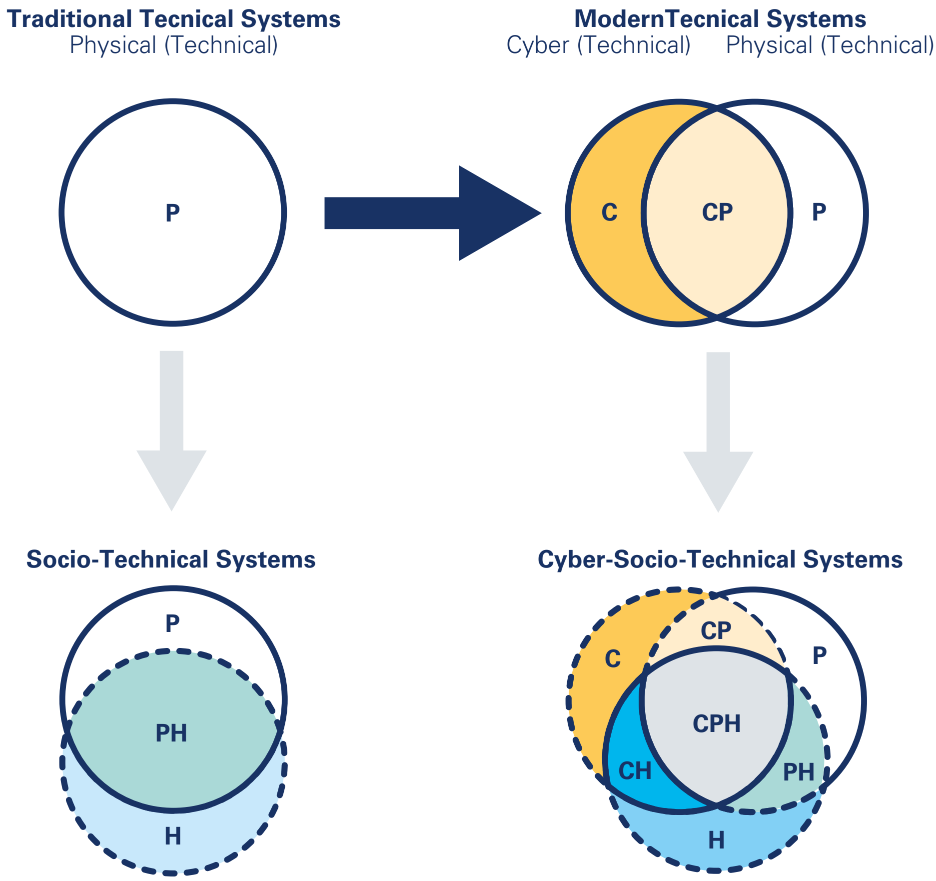
## 4.1 AUTOMATION IN CYBER-SOCIO-TECHNICAL SYSTEMS

Increased partial automation implies involving complex system element interactions between operators and machines, between individual operators, and between individual machines. Such modern working conditions may affect work practices and contexts on board. Some duties associated with particular ranks of seafarers could be automated with modern technologies. Cyber-Socio-Technical Systems (CSTS) involve an extensive mode of computational artefacts driven by data-accessing and data-processing services working with other interconnected entities,[39] such as shore-based operation centres.

Figure 3.13 illustrates the evolution of technical systems. Traditional technical systems are composed of physical devices (P), which evolve into socio-technical systems where physical systems (P) and human agents (H) interact. This system of machine-human interaction has been observed in the maritime industry when partial automation has been introduced, such as with ARPA. When ARPA detects a risk of collision and alerts deck officers, they assess the danger by combining the automated warning with a manual bearing of the target. This leads to decision-making by deck officers in terms of when and how to react to avoid collision. Indeed, human agents (seafarers) interact with physical systems (P) to achieve safe navigation.

Advanced contemporary technical systems, however, include a cyber (C) element (e.g., software systems with autonomy and intelligence) and a physical (P) element (e.g. hardware systems with modern physical devices, such as sensors and actuators). These two technical systems (cyber and physical) operate jointly to achieve their functional goals as Cyber-Physical systems (CP). Maritime robotics, airborne as well as shore-bound, are examples of CPs with capabilities of completing tasks through technical system interactions. With future maritime operations, Cyber-Socio-Technical Systems (CSTS) will see humans (H) and technical artefacts, such as cyber (C) and physical (P) artefacts, engage in social interactions, which in parallel will also engage with other multiple cyber (C) and physical (P) artefacts. These technical systems will in the future be used with ultimate autonomous systems, such as uncrewed vessels.

FIGURE 3.13 Evolution of technical systems towards cyber-socio-technical systems (CSTSs)




(Source: Patriarca et al., 2021)[39]

## 4.2 TASK AUTOMATION AND FUNCTION AUTOMATION

Partial automation may be introduced with tasks carried out by seafarers or with functions where various ship operations are combined. Task automation involves dealing with how tasks are performed from a seafarer perspective. Function automation, on the other hand, is a technology-driven perspective. Unless advanced technology is designed to replace human involvement, seafarers will remain in the loop of ship operations. Most discussions on technology focus on the transfer of onboard seafarer tasks to remote operators ashore. Seafarers often multitask and work intensely with complex systems. Even in the event where some seafarer duties are fully automated, monitoring tasks will continue to be performed by humans with computer assistance. Digital transformation extends beyond cognitive and manual routine tasks and includes analytical tasks, such as automated decision-making.[40] While the risk of task automation is high for certain occupational groups, such as ratings,[41] this is not expected to cause overall net job losses. Technology requires negotiating hurdles on a broad scale, affording time for workers to reskill and upskill to new tasks and new emerging jobs.[42] Research supports the perspective of technology as a job creator where employment growth is secured as product demand expands.[43]

As function automation becomes mature, affordable and more widely applied, the related technology behind will also grow more complex. However, automated functions may require the same resources as traditional operations, and companies may furthermore be reluctant to introduce such technology into well-established and proven systems due to a general lack of trust in technology.[44] Experts attending the workshops emphasized the importance of maintaining and upgrading advanced automation control systems to address potential machine operation errors, software problems and cyber-security issues. Although crew members are not expected to perform programming or quality improvement by themselves, there is a need for them to better understand automation.

It is also important to note that the behaviour, attitudes and technical as well as soft skills of seafarers are embedded in their work cultures and thus influence the entire process of ship operations. Function automation therefore not only affects workflow but is also an integral part of the safe and efficient management of systems and of onboard contingency planning. An example given in our workshops was Dynamic Positioning Systems (DPS), where operations are usually very smooth but where critical situations can arise.

Task and function automation requires continuous adaptation and learning as seafarer duties adapt to change. The STCW Convention prescribes seafarer competences based on a conventional understanding of their roles and responsibilities. However, insights garnered from the expert workshops indicate that there is an urgent need for the maritime industry to address the changes to onboard and onshore tasks and duties brought about by automation, digitalization, and decarbonization. Moreover, since automation and digital transition is likely to benefit not only shipowners but also seafarers with relevant skills, then appropriate skills training for seafarers is of paramount importance. Individuals with the right skills are more likely to find employment, adapt to disruptive change and sustain higher productivity.

## 4.3 NEW VALUES FOR SEAFARERS

The required skills and competences of seafarers are undergoing change due to job profile duties being automated, which affects the division of work between humans and machines. This implies that changes in seafarer jobs not only involve work processes and duties but also workplace values.

**From multitasking to specialists**

Seafarers generally multitask on board to deal with different managerial, operational and administrative tasks. Indeed, seafarers are expected to be self-sufficient in fixing small and large problems alike. When in the future some current onboard tasks become automated, seafarers will be expected to deal more with specialized tasks.

"Now we are talking about the future-ready maritime specialists – the shore-based operators (...) it's more than just a conventional officer of the watch."
(workshop participant from Asia)

**From invisible to visible workers**

The work of a seafarer is not often appreciated in the eyes of the public despite their indispensable contribution to society. Their invisibility as workers means that they are lesser valued than they should, which results in more vulnerable working conditions and fewer rewards. In smart and green shipping, new jobs will be created ashore. This transition to shore-based activity will make the work of a seafarer more visible to the public and therefore arguably more valued.

"We are going to rely on a new generation of seafarers (...) some people use the term e-farer. They are going to be a single species, which is completely different from the one we already have."
(workshop participant from the Pacific/Oceania)

**From negative to positive environmental impacts**

With marine and air pollution from daily operations or marine accidents, seafarers are often given the blame and stigmatized by the media. There have been few opportunities for seafarers to demonstrate their passion and commitment to protecting oceans. In the rush to decarbonize, seafarers can contribute to reducing emissions through ship operation and thereby become proud of their role as environmentalists.

"It will become more important to save fuel for a green operation."
(workshop participant from Scandinavia)

"[Seafarer] can include the optimization of how ships run, and reduce the carbon footprint and improve on the greenness."
(workshop participant from Asia)

**From hierarchy to equality**

Traditionally, onboard work has taking place in a hierarchical organization headed by the Captain followed by crew members according to their rank. With new technologies and a new distribution of duties among seafarers, this line of command may become less important. Technology may, for instance, impact communication, such as when reports are automatically generated and distributed more evenly rather than primarily being directed to the Captain. Consequently, future seafarers could experience a less hierarchical work organization.

"Everybody has got their really sharp competence that aren't inter-changeable. Everybody's opinions will matter very, very much to the ship."
(workshop participant from Scandinavia)

**From masculine to feminine jobs**

Ship operations are set to become more remote-operated what with maritime operations increasingly being shifted from ship to shore as a result of automation and digitalization. Traditionally, seafaring has been perceived as a male domain. This will change with the redistribution of operations, allowing the industry to tap into the behavioural competencies and potentials of such underexplored talents in the industry as women.

"There is more flexibility with digital skills and talent management. That is a reason why we went very much into behavioural competencies and assessing them on that as well."
(workshop participant from Asia)

**From hardware to software**

With newer ship designs, operations require connecting hardware and software, which should also be the focus of the training of seafarers. Different types of technical knowledge will be required, which also implies that seafarers need to be aware of different risks related to the hardware and software respectively.

"All of them [hardware and software knowledge] is somewhat covered by a sophisticated complex system, which is way more intelligent than me."
(workshop participant from Oceania/Pacific)

**From work-life conflict to work-life balance**

Many seafarers reported that their jobs come with a destiny of long separations from family and home. Such work-life conflicts may potentially be eased by automation and digitalization, which could improve the onboard connectivity to the shore as well as offering a better work-life balance with more shore-based career opportunities.

"In terms of career paths, there are options for them to work ashore so the system becomes more flexible."
(workshop participant from Europe)

"You more used connectivity to connect to your shore relatives and friends. But if you can get a better working environment on the ship, less night-shift work, it might also improve the social life on the ships, which also may make it more attractive for a lot of people."
(workshop participant from Scandinavia)

# 5 JOB OPPORTUNITIES FOR SEAFARERS

The changes seafaring is set to undergo through automation, digitalization and decarbonization will offer new job opportunities in the maritime industry, which in turn will require the upskilling and reskilling of seafarers. This section focuses on future job opportunities for seafarers and includes examples of new types of jobs in the format of a job atlas.

## 5.1 FUTURE JOB OPPORTUNITIES

From a career perspective, the future will offer opportunities for seafarers to switch from onboard jobs to shore-based positions. It is generally acknowledged in the industry that "ex-seafarers" are the best candidates for many shore-based positions. However, with technological development, the job profiles of shore-based employees will be affected, especially when including remote operations of onboard activities. As a result, shored-based employees may need reskilling. Table 3.D presents the perceptions of the survey respondents on the future job opportunities for seafarers.

TABLE 3.D Future trends in seafaring workforce

| FUTURE TRENDS IN SEAFARING WORKFORCE | LIKELIHOOD OF OCCURRENCE IN (%) |
|---|---|
| Seafarers in a rotation scheme (onshore-onboard-onshore) | 64.29 |
| Expansion in deployment of contractors doing specialized tasks | 64.14 |
| More attractive jobs for women seafarers (e.g. work in operation centres) | 64.14 |
| More attractive jobs for young seafarers (e.g. work in operation centres) | 63.86 |
| Institution of shore-based operation centres | 63.57 |
| Expansion of onshore workforce to run the shore-based operation centres | 60.57 |
| Possibility to outsource control centres operation to specialized contractors | 59.57 |
| Reduction in seafaring workforce due to advanced automation and digitalization | 56.00 |

(source: FOMJ survey)

During skill workshops, the experts agreed that advancements in digitalization and automation may pose an increased risk of job loss for seafarers in lower ranks, although they believe this will not change overnight. They also believed that supply and demand of labour in the maritime market will adapt and that an overall decline in employment opportunities within lower ranks will encourage younger generations to seek more training to secure higher-ranked positions. Furthermore, the experts suggested that some jobs could be transferred from shipboard jobs to portside opportunities.

Our studies indicate the emergence of new kinds of jobs in the maritime industry. Table 3.E includes examples of future job opportunities within different stakeholder categories. This is not a finite list and such job opportunities would also differ based on department, rank, experience, and location. The listed information was retrieved mainly from ESCO and the WMU analysis based on desk review.

Table 3.E lists examples of job titles or specialized areas that require further definition. The next subsection seeks to illustrate what such new future jobs for seafarers may look like in the format of a job atlas.

## TABLE 3.E Shore-based job opportunities for future seafarers

| STAKEHOLDER CATEGORIES | EXAMPLES OF STAKEHOLDERS | FUTURE JOB OPPORTUNITIES |
|---|---|---|
| **Technology & service providers** | **Equipment providers**<br>**Software providers** | • Trainer<br>• After-sales services technician<br>• Commissioning/Service engineers |
| | **Alternative fuel producers** | • Engineers with different expertise like chemistry, electrical, mechanical, etc.<br>• Experts to provide standards and guidelines for safe storage, bunkering, and usage of alternative fuels |
| | **Third party contractors** | **3rd party contractors to perform/run:**<br>• Maintenance<br>• Service of automation/control systems<br>• Training<br>• Audit/ Certification<br>• Robots and drones<br>• Port services |
| | **Insurance companies** | • Insurance underwriters/ Insurance rating analyst, familiar with new technologies in shipping |
| | **ICT companies** | • Cyber security: Cyber forensics expert- ICT security architect/engineer<br>• Human computer interaction: User interface designer<br>• Big Data Platform & Cloud service: Cloud engineer- ICT network architect- Database administrator<br>• Satellite and aerial communication: Information and communications technicians<br>• Digital twining & Internet of Things (IoT): Mechatronics engineer- 3D modeller<br>• Blockchain: Blockchain developer- Blockchain architect<br>• Artificial intelligence: ICT intelligent systems designer- Autonomous driving specialist<br>• Augmented Reality (AR)/ Virtual Reality (VR): Designer of ship simulators- computer-aided design operator |
| | **Financial firms** | • Credit analyst familiar with maritime industry and new technologies |
| **Shipowners/ operators** | **Shipping companies** | • ICT technicians, software developers, and cyber security experts in IT department<br>• Control centers in shipping companies<br>• Inspectors/Auditors in HSEEQ department<br>• Expedition teams for special maintenance and automation trouble shooting<br>• Corporate risk manager<br>• Experts in R&D department<br>• Financial risk analyst/ Investment adviser |
| | **Management companies** | • Vessel managers familiar with new technologies<br>• Recruitment experts accustomed with new skill/competency requirements for seafarers |
| | **Shore control centers** | • Trained navigational officers and marine engineers<br>• ICT specialists |
| **Education, training, & research** | **MET institutes** | • Designers/ Operators of advanced simulators and VR equipment<br>• Designers/ Operators of IT-based teaching aids<br>• Designers of Computer Based Training (CBT) program<br>• Career guidance advisor- Curriculum administrator |
| | **Universities/ Research centers** | • Research and development manager<br>• R&D engineer/expert<br>• Experts to conduct economic and technical feasibility studies |
| **Authorities & administrations** | **Maritime administrations** | • Technical and legal consultants to institutionalize new maritime laws in the framework of national laws |
| | **Port state control**<br>**Flag state control** | • Trained inspectors familiar with new technologies and relevant codes/ standards/ regulations |
| **Ports & Shipyards** | **Ports** | **Port operators engaged with:**<br>• Onshore Power Supply<br>• Battery charger<br>• Alternative fuel bunkering<br>• Port Communication/Digitalization<br>• Shore facility for reception of disposable material<br>• Circular economy and recycling of waste material<br>• Advanced cargo handling and mooring equipment<br>• Port pilotage service |
| | **Ship yards** | • 3D printing technician<br>• Naval architects and marine engineers accustomed with new technologies and relevant class rules |
| **Classification societies** | | • Trained surveyors to evaluate new technologies against codes/ standards/ regulations<br>• Operators of robots and drones in survey process<br>• Experts to provide standards and guidelines for application of new technologies<br>• Online surveyors |
| **Developing and least developed countries** | | • Securities analyst- Logistics analyst- Transport health and safety inspector |
| **Shippers/ consignees** | | • Legal advisers- Market research analyst/ Marketing consultant- Logistics analyst |
| **Regulators/Policy makers** | | • Maritime economists- Technical advisers- Maritime safety specialists |
| **Seafarers** | | • Specific ranks for specific job descriptions based on new technology applications (e.g. Cryogenic engineers for LNG/Hydrogen carriers) |

## 5.2 FUTURE JOB ATLAS

This section provides an atlas of future shore-based job opportunities for seafarers. Some of these professions already exist in the maritime job market. However, job applicants for such positions are required to possess new skills, such as knowledge of newly adopted maritime technologies and the latest ICT. Additionally, other jobs are new to the maritime market in general, such as ship operator positions at Shore Control Centres (SCC).

### Inspector/Auditor/Surveyor

Subject to reskilling in mid term

**Job description**

Marine surveyors/ inspectors/ auditors inspect vessels to assess, monitor and report on their condition based on the standards and regulations laid down by the IMO.

**Skills**

- ✓ Ability to use robots and drones where it is required
- ✓ Abilities to conduct on line survey
- ✓ Digital and IT skills, at least at the level of MS office package
- ✓ Updated with the latest IMO approvals and resolutions
- ✓ Knowledge of Harmonized System of Survey and Certification (HSSC)

**Workplace**

Shipping companies, port/flag state authorities, classification societies

### Commissioning engineer

Subject to reskilling in short term

**Job description**

Commissioning engineers are responsible for overseeing the final stage of a project, which include the installation and testing of systems. They ensure that the equipment, facilities, and plants are functioning according to specifications and requirements.

**Skills**

- ✓ Write work-related reports
- ✓ Use testing equipment
- ✓ Use measurement instruments
- ✓ Ensure fulfilment of legal requirements
- ✓ Knowledge of quality assurance procedures
- ✓ Knowledge of quality standards

**Workplace**

Shipping companies, shipyards, technology provider companies, third party contractors

Results from the expert workshops and the surveys fielded for the project demonstrate that the examples of new job opportunities within the maritime industry presented above all require mastering digital skills and keeping abreast with the latest developments in industry practice, regulations and standards. The industry must therefore help seafarers' adaptation to onboard and/or onshore market demands within smart and green shipping.

### Instructor/ Trainer

Subject to reskilling in mid term

**Job description**

Instructors/Trainers design training courses on a particular technical knowledge and skills. They produce a syllabus, including intended learning outcomes, assessment, contents, training materials and delivery methods (e.g., on site, online, hybrid).

**Skills**

- ✓ Knowledge and skills of curriculum/course development and delivery
- ✓ Experience in teaching, especially with modern training technique and tools
- ✓ Excellent communication skills with good proficiency of English
- ✓ Situation awareness to understand learner diversity and different contexts when teaching modern technologies

**Workplace**

METIs, shipping companies, technology provider companies, third party contractors

### Service technician

Subject to reskilling in short term

**Job description**

Marine maintenance/ service technicians work on engines, navigation equipment, operating systems, pumps, and other machineries on board, utilizing their knowledge, skills and experiences.

**Skills**

- ✓ Working knowledge of tools and equipment used in marine maintenance
- ✓ Ability to read and understand technical manuals
- ✓ Good verbal and written communication skills
- ✓ Good customer service skills

**Workplace**

METIs, shipping companies, technology provider companies, third party contractors

### Remote Control Center Operator (RCCO)

New job vacancy

**Job description**

RCCO monitors the vessel operations and intervenes remotely where necessary and technically feasible. An RCCO can monitor/support/control more than one vessel. RCCO has responsibilities for the integrity and safety of autonomous, remotely operated and remotely supported vessels. (source: DNV-ST-0324)

**Skills**

- ✓ The minimum level of knowledge and skills for remote control operators related to navigation, machinery, communication and cargo.
- ✓ Specific details related to all ship and remote control centre-specific arrangements and systems.
- ✓ See more details in DNV-ST-0324.

**Workplace**

Shore Control Centers (SCC)

### R&D engineer/expert

New job vacancy


**Job description**

Research engineers/ experts combine research skills and knowledge of engineering principles to assist in the development or design of new products and technology.
They also improve existing technical processes, machines and systems and create new, innovative technologies (Source: ESCO).

**Skills**

- ✓ Execute feasibility study
- ✓ Define technical requirements
- ✓ Gather experimental data
- ✓ Perform scientific research
- ✓ Scientific research methodology
- ✓ Engineering processes

**Workplace**

Universities, research centers

### Port technician
New job vacancy

**Job description**

Port technicians are responsible for maintenance and operation of new technologies such as onshore power supply, equipment to charge the vessels' battery, alternative fuel bunkering infrastructure, and other shore facilities.

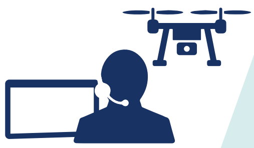
**Skills**

- ✓ Knowledge and practical skills of marine electro-technology
- ✓ Knowledge and practical skills of marine engineering
- ✓ Well familiar with alternative fuel properties
- ✓ Knowledge of alternative fuel standards (e.g. provided by classification societies)

**Workplace**

Ports

### Robot/Drone operator
New job vacancy



**Job description**

Drone pilots remotely operate uncrewed aerial vehicles (UAVs). They navigate the drone as well as activate other equipment as cameras, sensors as LIDARS to calculate distances, or any other instrumentation. Industrial robot controllers operate and monitor industrial robots used in automation processes to perform various manufacturing activities such as lifting, welding and assembling (Source: ESCO).

**Skills**

- ✓ Test instrumentation equipment
- ✓ Perform flight maneuvers
- ✓ Comply with air traffic control operations
- ✓ Operate radio navigation instruments
- ✓ Have spatial awareness
- ✓ Ensure public safety and security
- ✓ Maintain robotic equipment
- ✓ Maintain control systems for automated equipment

**Workplace**

Port/flag state authorities, classification societies, ports, shipyards

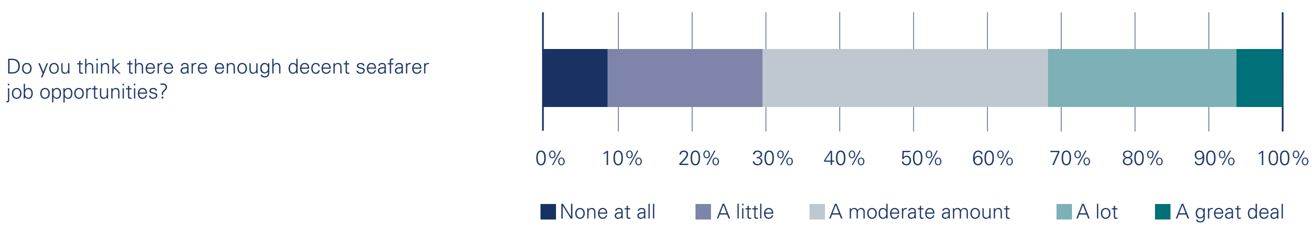
# 6 LIFELONG LEARNING IN MET AND SEAFARER CAREERS

Our analysis of future skills and competences indicates a need for skills development to become an element of formal maritime education and for seafarers to embrace lifelong upskilling and reskilling. Based on the recommendations given by experts attending the skills workshops, this section begins with a MET gap analysis on how seafarer training can bridge the skills gaps. Our study points to the importance of lifelong learning and to the necessity of shipping companies supporting seafarers in keeping their knowledge and skills up-to-date in a changing world of work. Furthermore, a seafarer career model is introduced to embrace a holistic concept of human resource development and identify sustainable solutions for recruiting skilled workers for the maritime sector.

## 6.1 MET GAP ANALYSIS

The role of MET is to prepare prospect seafarers for their jobs by giving them the necessary qualifications and skills to operate ships in a safe, efficient and environmentally sound manner. The international standards for seafarer competences are prescribed by the STCW Convention. METIs design and develop their curricula to train seafarers in accordance with national legislation adopted in alignment with international standards. While implementing STCW in the design and delivery of a MET curriculum poses challenges in some countries, maritime cadets also struggle to complete their mandatory onboard training to obtain a CoC. Subsequently, less than 20% of Filipino cadets are able to complete their training.[45] More than half of Indian deck cadets fail to complete their training successfully, while Indian engine cadets fare slightly better with over half of them managing to complete their training.[46] In 2021, 48% of METIs reported more than half of their officer graduates finding initial employment as ratings, while 10% of METIs indicated that rating trainees found it "very difficult" to find a berth.[47] These ship-related issues for cadets, where the industry often fails to fully support the implementation of STCW, should be noted when discussing the current shortage of competent seafarers. In our seafarer survey, most respondents (70.2%) believe that there are enough decent jobs available. Almost a third (29.8%) believe that there are little to no opportunities (Figure 3.14). Furthermore, younger generations of respondents tend to feel negative about the availability of decent job opportunities compared to older generations.

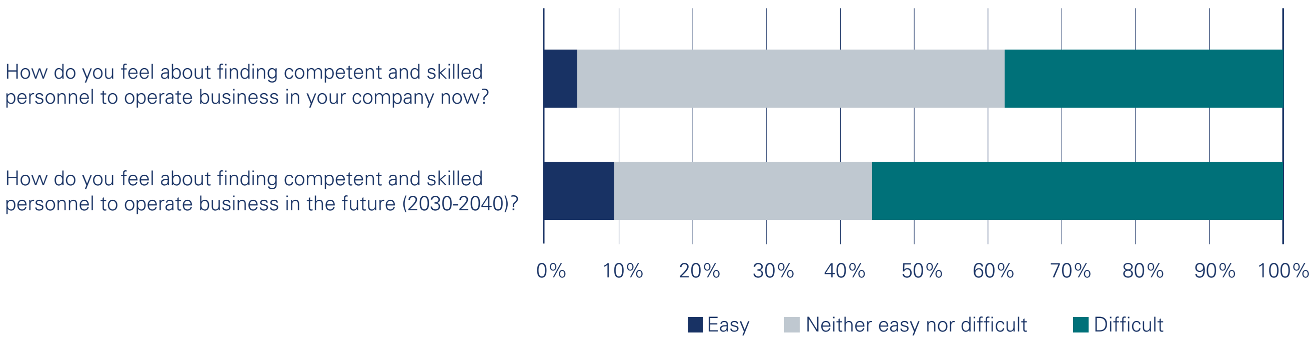
FIGURE 3.14 Decent seafarer job opportunities as perceived by seafarers




(Source: WSLFSS 2022)

Our survey asked company managers how they viewed the current and future (2030-2040) potential of sourcing competent and skilled workers for their company. With both scenarios, only few respondents felt it was easy (4.8%, 9.6% respectively). However, the responses varied since the majority (57.8%) found it "Neither easy nor difficult" in the present, whereas the majority (55.4%) believed that it would become "difficult" to find competent and skilled workers to operate business in the future (Figure 3.15).

FIGURE 3.15 Finding competent and skilled personnel now and in the future




(Source: FOMJS 2022)

Table 3.F offers an overview of the current and future (2031-2040) ease of finding competent and skilled workers for shore-based activities as perceived by respondent companies. Overall, the responses indicate few current barriers in recruiting competent and skilled workers compared to expectations for the future. More importantly, there seems to be a shift in pattern as to which countries workers are recruited from. Shipping companies expect to rely less on METIs in the future when sourcing a competent and skilled workforce.

Companies expect difficulty in recruiting competent and skilled workers in the future. There is a fall in expectation when it comes to: Recruiting mid-career and shore-based maritime personnel (-20.0%); Recruiting ex-seafarers (-18.5%); Training existing seafarers for upskilling (-15.4%); Recruiting foreign seafarers (-11.5%); Training existing employees for upskilling (-10.8%); Recruiting fresh graduates from maritime training institutions (-10.0%); Recruiting from third-party crewing agencies' (-5.4%).

However, companies expect to facilitate the recruitment of competent and skilled workers in the future through: Recruiting fresh graduates from other (non-maritime) educational institutions (+12.3%); Outsourcing management or special activities (+10.8%); Recruiting part-time/temporary employees (+6.9%); Outsourcing part of vessel operation functions (+4.6%); Recruiting part-time/temporary operation staff (+3.8%).

It appears that the recruitment of women seafarers for the future workforce is not considered of strategic importance by shipping companies since expectations for current and future recruitment levels regarding this issue seem very similar (+0.7%). However, when responding to the survey question as to whether digitalization would provide more attractive jobs for women seafarers, companies expected moderate to high probability (with a mean of 4.19, 95 CI [3.86, 4.52] in 7 Likert scale). There is therefore an indicative potential to attract women seafarers to the future maritime industry, although shipping companies may also find alternative ways of recruiting sufficient male seafarers.

Similarly, responses to the survey question regarding the future attractiveness of the industry to younger seafarers (by 2040) were moderate in expectation (with a mean of 4.00, 95 CI [3.68, 4.32] in 7 Likert scale). This implies that METIs will experience greater difficulty in attracting young people due to uncertain job prospects. Such views present a challenge for the maritime industry where there is a need to recruit sustainable levels of graduates in the future, which will require younger generations to recognize the opportunities offered by pursuing maritime careers or transitioning into maritime jobs. The current reluctance of employers to upskill and train their existing workforce and hire foreign seafarers is also set to cause challenges with recruitment and retention, particularly in nations in the northern hemisphere with ageing populations. The industry needs to consider how to create greater awareness of the opportunities of the maritime professions among younger generations, who may otherwise perceive greater opportunity in other industries.

TABLE 3.F Where do you find a competent and skilled workforce for shore-based activities in your company currently as well as in the future (2031-2040)?

| WHERE TO FIND COMPETENT AND SKILLED WORKFORCE FOR SHORE-BASED ACTIVITIES | CURRENT | | TREND | FUTURE (2031-2040) | |
|---|---|---|---|---|---|
| | FREQUENCY | PERCENT | | FREQUENCY | PERCENT |
| Recruiting mid-career and shore-based maritime personnel | 65 | 50.0 | ↓ (-20.0%) | 39 | 30.0 |
| Recruiting ex-seafarers | 68 | 52.3 | ↓ (-18.5%) | 44 | 33.8 |
| Training existing seafarers for upskilling | 68 | 52.3 | ↓ (-15.4%) | 48 | 36.9 |
| Recruiting foreign seafarers | 57 | 43.8 | ↓ (-11.5%) | 42 | 32.3 |
| Training existing employees for upskilling | 62 | 47.7 | ↓ (-10.8%) | 48 | 36.9 |
| Recruiting fresh graduates from maritime training institutions | 62 | 47.7 | ↓ (-10.0%) | 49 | 37.7 |
| By third party crewing agencies | 53 | 40.8 | ↓ (-5.4%) | 46 | 35.4 |
| Recruiting non-maritime personnel | 44 | 33.8 | ↓ (-2.3%) | 41 | 31.5 |
| Recruiting consultants | 34 | 26.2 | ↓ (-1.6%) | 32 | 24.6 |
| Recruiting women seafarers | 47 | 36.2 | → (+0.7%) | 48 | 36.9 |
| Recruiting part-time/temporary operation staff | 24 | 18.5 | ↑ (+3.8%) | 29 | 22.3 |
| Outsourcing part of vessel operation functions | 24 | 18.5 | ↑ (+4.6%) | 30 | 23.1 |
| Recruiting part-time/temporary employees | 23 | 17.7 | ↑ (+6.9%) | 32 | 24.6 |
| Outsourcing management or special activities | 19 | 14.6 | ↑ (+10.8%) | 33 | 25.4 |
| Recruiting fresh graduates from other (non-maritime) educational institutions | 22 | 16.9 | ↑ (+12.3%) | 38 | 29.2 |

(Source: FOMJS 2022)

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## 6.2 EXPERT RECOMMENDATIONS

The skills workshops concluded with recommendations from the expert participants on how to resolve the skill gaps identified by them. The major focus of the recommendations was on training seafarers, with consideration given to the individual role of each stakeholder. Table 3.G presents the areas for improvement in Syllabus/Curriculum and MET, while Table 3.H shows the areas for improvement in IMO/STCW,[i] Shipping companies and Technology providers.

TABLE 3.G Expert recommendations in MET and syllabus/curriculum

| MET | SYLLABUS/ CURRICULUM |
|---|---|
| • Regular train-the-trainer of MET teachers with new technologies.<br>• Sharing good practices among METIs around the world.<br>• Collaborating with Maritime Technology Cooperation Centres (MTCCs) to update knowledge and skills.<br>• Creating a Community of Practice (CoP) with maritime stakeholders in R&D.<br>• Educating MET experts in higher education, such as WMU and IMLI.<br>• Benefiting from the ERASMAS+ programme to mobilize teachers and students between METIs. | • Digital and soft skill training as part of curriculum.<br>• Modernizing the existing curriculum.<br>• Involving all stakeholders in the process of new curriculum design.<br>• Flexibility in the syllabus to accommodate emerging subjects.<br>• Involving industry R&D to benefit from the latest training development.<br>• Focusing on the architecture of digitized systems as well as its operation.<br>• Using advanced simulation/real-time training.<br>• Gender-mainstreaming in syllabus/curriculum development, delivery, and assessment. |

TABLE 3.H Expert recommendations in STCW, shipping companies, technology providers

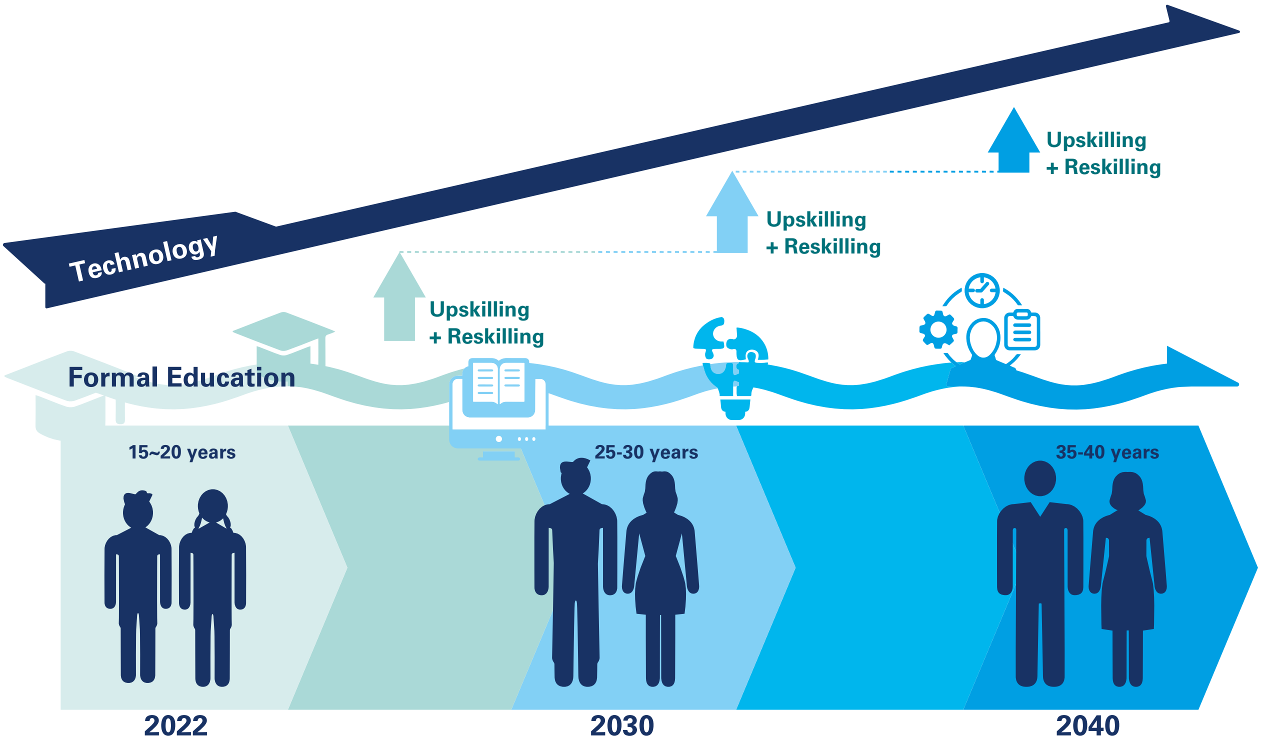
| STCW | SHIPPING COMPANIES | TECHNOLOGY PROVIDERS |
|---|---|---|
| • Engaging with stakeholders in the Comprehensive Review of STCW.<br>• Optimizing the requirements for seafarer education, training and certification.<br>• Facilitating knowledge sharing, including good practices, among the IMO Member States on new regulations.<br>• Addressing gender equality and promoting safe working environment. | • Investing on seafarers' lifelong learning.<br>• Providing financial support for seafarer training and certification costs.<br>• Offering e-learning to minimize training interventions during seafarers' vacations.<br>• Ensuring gender equality policies in place and promoting safe work environment. | • Providing technical training to companies and METIs.<br>• Including seafarers as users in technology design processes.<br>• Ensuring the availability of technology specialists when seafarers need technical assistance. |

## 6.3 UPSKILLING AND RESKILLING THROUGH LIFELONG LEARNING

The technology roadmap presented in chapter 2 identifies key trends and technologies influencing future maritime jobs, including opportunities, threats and policy developments. Different trends and technologies are expected to impact maritime jobs in the short-term (2022-2026), medium-term (2027-2030) and long-term (2031-2040). The pace of technological advancement and its impact on maritime jobs may vary by country and region. However, a global maritime labour market will continue to search for talents and competent personnel to meet the industry's changing needs. Historically, industrialization and technological progress has changed and shaped the labour market. Current developments in the market are anticipated to lead to large-scale structural unemployment for redundant workers where millions of people will need to find a new job in a complex world.[48]

[i] A Comprehensive Review of STCW Convention and Code has been in discussion at the IMO HTW. Possibilities for ship operation offered by digitalization and emerging technologies will impact on seafarer education, training and certification, which will be addressed in the review and revision processes.

FIGURE 3.16 Upskilling and reskilling through lifelong learning




Formal education in general is expected to focus on science and the arts with increased emphasis on digital pedagogies. The adaptability of formal education to new technology and to providing teaching skills for rapidly changing environments is limited due to the time it takes for educational authorities to implement updated regulations. The 12-month mandatory onboard training for CoC has been part of the IMO discussion on whether such training can be replaced by simulator training.[i] Technical Vocational Education and Training (TVET) will also support learners in gaining job-specific skills, yet as technology evolves, it will remain necessary for workers to constantly upskill and reskill through lifelong learning (Fig.3.16).

The employer survey (FOMJS 2022) indicates that employers will be less interested in upskilling their seafarers (-15.4%) and employees (-10.8%) in the future. Training offered by employers would furthermore be affected by the world economy and crises such as the COVID-19 pandemic. Despite a consistent growth trend of training budgets for vessel operators before the 2020 COVID-19 pandemic, roughly 30% of vessel operators decreased their training budget. While more than half of seafarers (56%) funded their own training in full; 28% of seafarers shared nearly half of training cost with their companies, and only 16% were fully funded for training.[49] Such training costs include not only the upskilling and reskilling of competences to support their seafarer careers but also refresher courses and revalidation of certificates in order to simply retain their jobs as seafarers. In this context, upskilling may be perceived as a luxury and possibly as a burden by seafarers since the current training mechanisms often do not support lifelong learning.

Nevertheless, to manage their careers during transition periods, seafarers need to become self-guided learners and designers of their own career paths where financial support from companies and the State is crucial. The workshop participants embraced the notion of lifelong learning supported by self-directed learning, including e-learning, blended learning, problem-based learning, experiential learning and case study approaches. Lifelong learning is the guiding principle of the national strategy of Singapore, where uniform standards for training, assessment and the credentialing of skills and competency have been adopted across the nation's industries. Such ownership by the States through public policies would be of key importance in preparing the workforce for the future of work. Table 3.I shows examples from selected countries of governmental initiatives promoting digital skills.

[i] The IMO HTW 10 will continue to discuss the matter of facilitating mandatory seagoing service for trainees within the scope of the Comprehensive Review of the STCW Convention and Code.

TABLE 3.I Examples of governmental initiatives to promote digital skills

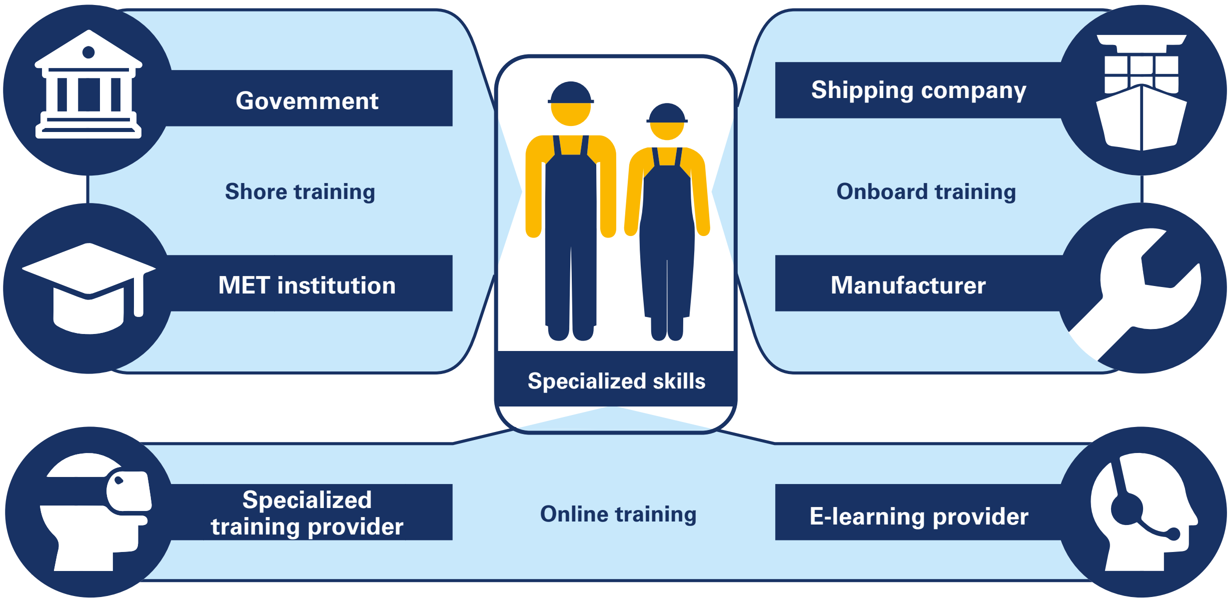
| COUNTRIES | EXAMPLES OF INITIATIVES |
|---|---|
| **Australia** | Digital Economy Strategy |
| **Brazil** | E-Digital strategy |
| **Canada** | Innovation and Skills Plan |
| **China** | Internet Plus Strategy |
| **Denmark** | Digital Growth Strategy |
| **Estonia** | Digital Agenda 2030; ProgeTiger programme |
| **France** | National Plan for Digital Inclusion |
| **India** | Digital India |
| **Japan** | Smart Japan ICT Strategy |
| **Malaysia** | National e-Commerce Strategic Roadmap; National Policy on Industry 4.0 |
| **Netherlands** | Dutch Digitalization Strategy 2.0 |
| **Philippines** | E-Commerce Roadmap |
| **Portugal** | National Imitative on Digital Competences 2030 |
| **Republic of Korea** | Creative Economy |
| **Singapore** | SkillsFuture Singapore; Digital Economy Framework for Action |
| **South Africa** | National Digital and Future Skills Strategy |
| **Spain** | Digital Spain Agenda 2025 |
| **Thailand** | Digital Economy and Society Development Plan |
| **United Arab Emirates** | National Digital Participation Plan |
| **United Kingdom** | Skills Bootcamps; Digital Skills Council; Maritime 2050 strategy |

## 6.4 FUTURE TRAINING

The current industrial education model where a static set of skills prepares workers to complete routine tasks has become outdated since adaptation to a complex new world requires constant upskilling and reskilling. Formal education cannot provide the flexibility required for the increased demand for new knowledge and skills. New training providers are therefore set to emerge, targeting the development of new industrial skills, such as creative and engineering skills, emotional and system intelligence.[50]

Diversified training opportunities were mentioned by shipowners and managers in our study. An increasing need for a skilled workforce would lead to a greater emphasis on training in the maritime industry. As a part of Maritime UK, the Maritime Skills Commission has emphasized the need for MET modernization in terms of developing course content and exams that are more relevant to modern shipping.[51] While the UK Government and METIs will continue to provide shore-based formal training, shipping companies and manufacturers are also set to offer onboard training for the upskilling and reskilling of seafarers. Other specialized training and e-learning providers will furthermore prepare online training, allowing seafarers to upskill and reskill on demand (Fig. 3.17). Though the modes of training – shore-based, onboard or online – can be a mixed match, existing METIs clearly cannot respond to all industry training needs, which is why certified training will be offered by various training providers. "Remote training, life-long education and career development should be further developed to more flexible options", a Greek shipowner stated (FOMJS 2022).

FIGURE 3.17 Training provider concept map




Future training will be increasingly conducted online or be Cloud-based. This requires seafarers to possess a level of digital competence to access training and succeed. Such global/online training platforms would require seafarers to be proficient in English, although online translation software tools could also be used. The inclusion of AI and chatbots in training programmes could require learners to be aware of what kind of linguistic syntax is comprehensible to machines. One workshop participant anticipated that "initial understanding of AI with a focus on digital skills" would become relevant in the medium-term (2027-2030).

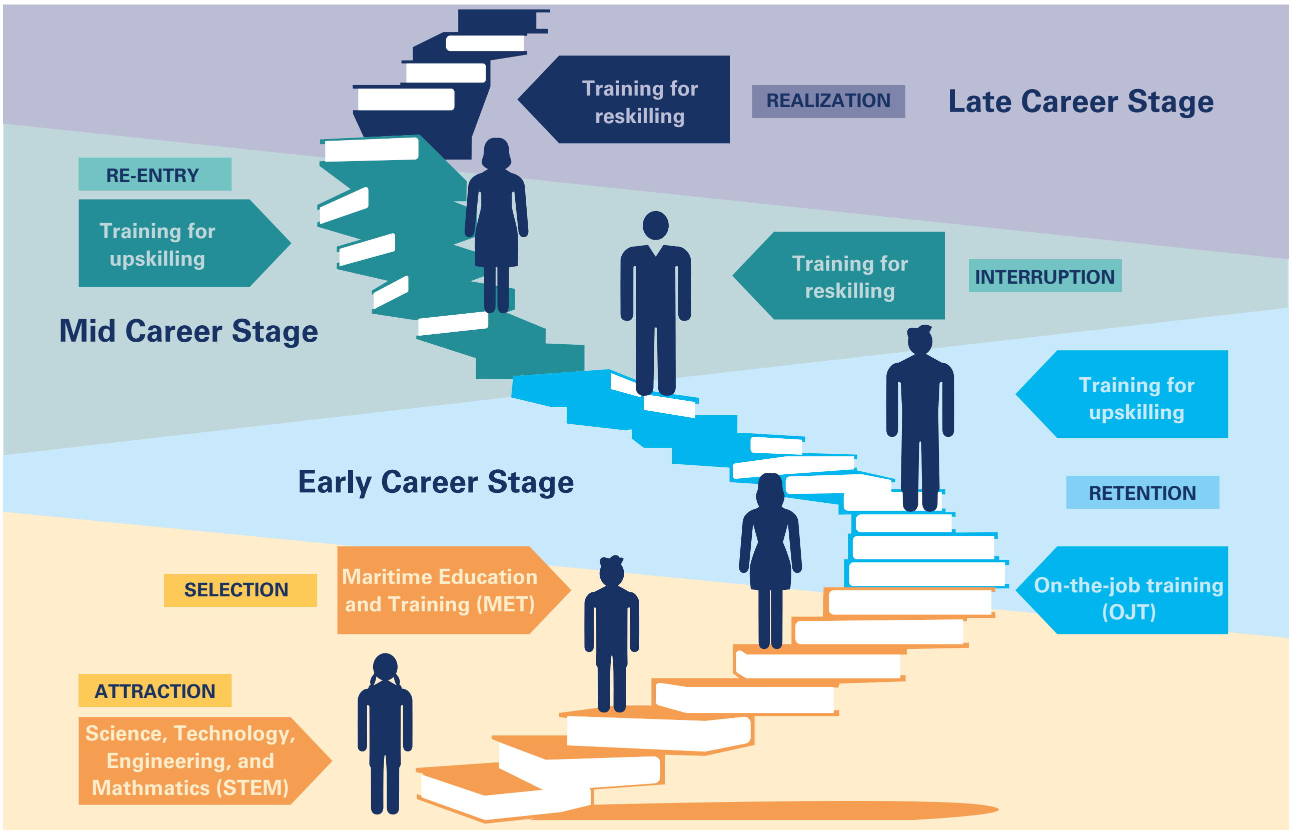
The formal education offered by METIs will continue to fulfil the current STCW requirements despite the overall transformation of job-related training. Add-on certificates achieved through special training (e.g. tanker training) will allow seafarers to prove their additional competencies. Future developments may include the emergence of self-organized knowledge communities where seafarers share their applied knowhow in cyber-socio-technical systems. Such informal online knowledge communities could potentially become a powerful tool for seafarers, allowing them to learn from a community of practice. Digital technologies will empower seafarers to access new knowledge, although workers also need to develop critical thinking and analytical skills to determine the value of information for specific problem-solving tasks. Such soft skills are often not fully fostered in formal education, which is why lifelong learning is necessary to ensure the acquisition of such skills.

## 6.5 SEAFARER CAREER MODEL

Our world is constantly evolving with new policies, technologies, social needs, economic incentives and environmental ethics, which makes it difficult to predict the future and adapt to a new world. A linear viewpoint of forecasting future job profiles based on current workplace requirements has limited value. Nevertheless, the human life cycle is relatively stable. From birth to nursery; from primary school to secondary and higher education; from employment to retention where some may face family care responsibilities; and finally, re-entry to the same or different profession until retirement with pension. Our life cycle will not change drastically compared to many other future variables.

According to ILO,[52] a career cycle for transport workers consists of 6 career phases: "Attraction" to the fields of Science, Technology, Engineering and Mathematics (STEM); Consequently choosing MET (i.e. "Selection"); Upskilling through onboard and shore-based training (i.e. "Retention"); Possible "Interruption" due to family care responsibilities; Re-skilling and upskilling for "Re-entry" to the same or other maritime jobs; and further re-skilling and upskilling for "Realization" of career aspirations (Figure 3.18).

FIGURE 3.18 Future seafarer career model




Seafarer careers are hierarchical in nature (i.e. rank-based) and flexible (i.e. working by voyage contract).[53] A formal MET education can provide a standard certification for officers, and specific training can help ratings find jobs. Upskilling through training offers seafarers the chance to work on specific types of ships, while assuming different responsibilities. Reskilling helps seafarers find work ashore in various positions. However, with future seafarer careers, roles and responsibilities may change faster than is the case today. The technology roadmap indicates that short-term and medium-term trends and relevant technologies will become game-changers of the maritime industry. Overall, the majority of seafarers surveyed (67.9%) believe that their employers have provided sufficient training for their current job. However, about a third indicated that they only received little or no training at all (Figure 3.19). Seafarers are required to gain the knowledge and skills necessary to manage the new technologies adopted by the companies they work for. Although companies need to invest in reskilling their staff, seafarers must also to a greater degree become self-guided learners and increase their autonomy and flexibility in designing their own careers.

Finding a shore-based job suitable for their career aspirations is up to the individual seafarers. However, the most important determinant for job change within the maritime sector according to respondents is neither career achievement nor experience but the availability of job opportunities. Asked whether they believe there are enough onshore employment opportunities should they decide to leave the seafarer profession, about a third of respondents (35.4%) indicated expecting moderate to high opportunity, while the majority (45.7%) indicated little opportunity, and almost a fifth (18.9%) believe there are no opportunities at all (Figure 3.20). Compared to their older peers, younger generations of respondents tend to be negative about the outlook for onshore job opportunities.

Nevertheless, the seafarer career cycle is generally applicable and relevant when considering which staff members are to be trained, upskilled and reskilled to ensure an adequate workforce for the maritime industry. As reported earlier, attracting younger generations and women seafarers, while ensuring the retention of current staff and the re-entry of experienced officers and ratings, is key to ensuring a sufficient workforce for the future of smart and green shipping.

FIGURE 3.19 Training provided by the current employer

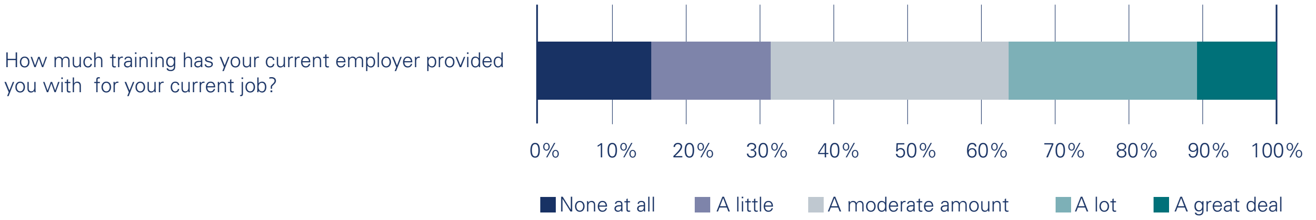
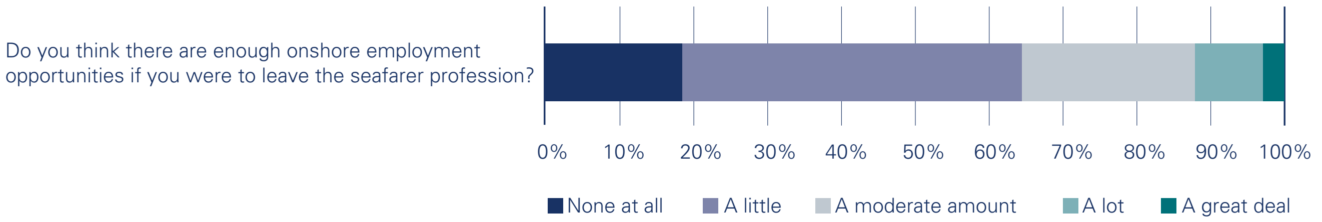



FIGURE 3.20 Onshore employment opportunities perceived by seafarers



# 7 SUMMARY AND RECOMMENDATIONS

This chapter has examined the potential positive effects on maritime competencies, skills, and new career opportunities brought about by future trends and technologies related to automation, digitalization, and decarbonization. The surveys and workshops conducted as part of the project along with an analysis of the relevant literature consistently point to the necessity of seafarers acquiring skills within digital and green technology. This chapter has identified the importance for the future of the industry to nurture a dynamic relationship between onboard and onshore occupation and competencies.

This chapter furthermore identifies the necessity of making the maritime transport sector more inclusive for women and younger generations as well as more resilient to the varied impacts of new technologies on the different segments and skills groups of the maritime industry.

Recommendations for the provision of timely and essential training and education for seafarers were also presented in this chapter. Consistent with the findings from the previous phase of the project, the overall changes to working in the maritime industry in the future promise to be manageable. However, a successful transition requires industry stakeholders to invest in training and to ensure that the future of work in the maritime sector remains attractive.

## 7.1 KEY FINDINGS OF CHAPTER 3

The key findings of chapter 3 in relation to the maritime competences, skills and career opportunities for current and future seafarers:

- Seafarers will remain in demand in the future. The recruitment of younger generations of seafarers will need to look beyond current demographics, which will be necessitated by the growing need for digital skills to operate smart and green ships. Africa, the Americas, and Pacific/Oceania will offer a potential resource of young workers for the global maritime labour market.
- Future maritime jobs will be increasingly shore-based and either partially or fully automated. This will presumably make the maritime job market more attractive to women seafarers. However, our survey indicates that the interest among employers in recruiting women seafarers will remain unchanged.
- Soft skills will remain decisive for future seafarers. Our study indicates that soft skills are of importance no matter the time horizon, whether in the short, mid, or long-term.
- Major skill gaps were identified regarding digital and systems analysis skills as well as technical skills related to immature technologies (e.g. alternative fuels, electrified propulsion systems, wind-assisted technologies). Moderate skill gaps were observed with technical skills related to existing/emerging technologies (e.g. energy efficiency measures, real-time monitoring system, and advanced navigational equipment) as well as with critical soft skills (e.g. critical and analytical, active learning, communication, problem-solving).
- The maritime industry needs to support the upskilling and reskilling of seafarers. With new jobs and alternative careers, officers at management and operational levels will need to upskill, while ratings at support level will need to reskill.
- Lifelong learning is key to the upskilling and reskilling of future maritime professionals. Some shipping companies provide training, while the cost of training is often either partially or fully borne by the seafarers themselves.
- Competences and certifications required for smart and green shipping are not always provided by the formal education of METIs. New training providers, such as manufacturers and software companies, are already joining MET domains to upskill and reskill seafarers.
- Experts predict the emergence of new seafarer work values, including seafarers being more specialized, visible, sustainability-conscious, equality-minded, less male-oriented, software-knowledgeable, and work-life balanced.
- The industry must support seafarer career development through lifelong learning.

## 7.2 RECOMMENDATIONS FROM CHAPTER 3

The following nine recommendations have been drawn from the analysis presented in chapter 3:

1. Engage with the maritime industry to establish regular dialogues on seafarer skill gaps and the seafarer labour market.

2. Create a portfolio of seafarers with digital and green skills to visualize their competences and build confidence and capacity.

3. Diversify the recruitment of future seafarers in terms of age, gender, and nationality by promoting maritime careers in partnership with governments, industry and maritime training institutions.

4. Stay up-to-date with the comprehensive review of the STCW Convention and Code, which may affect seafarer competences and certifications.

5. Identify the needs of upskilling and reskilling among different groups of seafarers on different types of ships and support their needs for lifelong learning opportunities.

6. Promote and share information on technology advancement and relevant training opportunities for seafarers in partnership with technology providers, METIs, and research organizations.

7. Mobilize funding among maritime stakeholders to ensure that upskilling and reskilling training costs are not borne by seafarers as beneficiaries.

8. Identify and promote good practices of companies that support the lifelong learning opportunities and career development of seafarers.

9. Align with governmental initiatives and strategies to promote digital and soft skills at the national and local levels and ensure that seafarers benefit from such ongoing national programmes.

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CHAPTER 4

# MARITIME COUNTRY PROFILES

4

**Authors:** Khanssa Lagdami and Fabio Ballini

# SUMMARY

The Maritime Country Profiles is an updated, expanded and refined assessment that builds on the Country Profiles introduced in the report entitled Transport: Automation, Technology, Employment – The Future of Work. The Maritime Country Profiles offer an assessment of the current state of play of a number of countries in terms of maritime innovation, technology adoption and other related factors. The countries are ranked by their score. Their overall score is based on five equally weighted factors: 1. Technology and Innovation Environment and Technology Feasibility; 2. Labour Market and Human Capital; 3. Economics; 4. Social Acceptance; 5. Regulation and Governance. The number of countries assessed has been expanded to encompass 20 nations from all continents. The survey is based on the first-ever large-scale maritime opinion survey targeting maritime leaders, managers, executives, and administrators on the state of play of the maritime technology development in their countries.[a] The collected data is combined with hard data and seafarers' data within 82 sub-factor fields taken from the Country Profiles. These sub-factors assess the state of play within the five main factors and provide a global maritime country profile score on maritime innovation and technology adoption.

This chapter of the report is divided into three main sections: 1. Maritime country profile factors as a tool to assess the readiness of a country to adopt new and emerging technologies in the maritime sector; 2. Key findings containing the main messages from the review of developments across the maritime country profiles; 3. detailed maritime country profiles (at the end of the report). Technical notes containing details on how data was aggregated (Annex E).

An analysis of the results from the list of the 23 countries leads to the five following key findings:

1. **Overall lack of mature readiness regarding the technology environment and business activeness**

2. **Flatting values in the Economy and Business sector**

3. **Promising trends within social acceptance and regulation and governance for developing countries**

4. **Promising tendency in the labour market and human capital field**

5. **Promising trend for closing the gap between developed and developing countries**

[a] Their country refers to the country where the respondents of the survey develop most of their professional activity.

# 1 INTRODUCTION

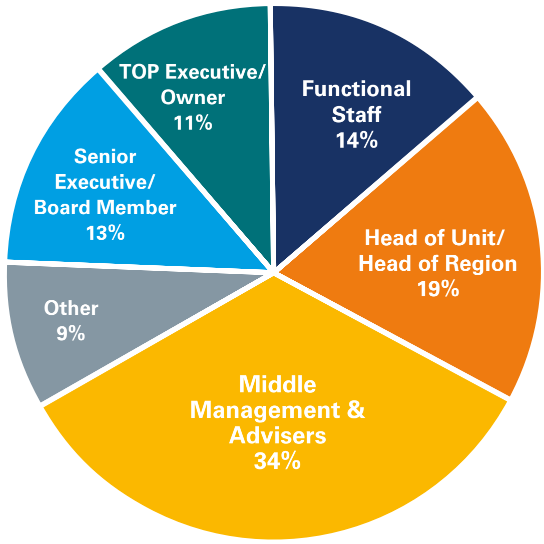
The Maritime Country Profiles aim to assess the state of play of countries regarding maritime technology adoption. The current expanded and refined approach to Phase 1 in the Maritime Country Profiles assessment provides an in-depth insight into the maritime sector for a set of countries, relying on original data collected for this purpose. The Maritime Country Profiles build on the successful undertaking by the World Economic Forum (WEF) and are based on answers from a worldwide network of maritime leaders and experts regarding various aspects that affect the maritime sector in the country where they work.

The Maritime Country Profiles follows the TechAdo[1] model, which provides the analytical framework for modelling technological innovation within maritime transport, focusing on policy-related factors. This multi-factor model extends the previous model of the World Maritime University[2] and provides its theoretical foundations. We have adopted a five-pillar version in which we disentangle the enabling environment into social factors, regulation and governance. The final model is grounded on five indicators:

1. **TECHNOLOGY AND INNOVATION**
2. **LABOUR MARKET AND HUMAN CAPITAL**
3. **ECONOMICS AND BUSINESS**
4. **SOCIAL ACCEPTANCE**
5. **REGULATION AND GOVERNANCE**

The survey questionnaire used as the main data collection tool was divided into the same categories as the model, and the questions were inspired by the WEF executive opinion survey. The WEF survey approach has stood the test of time and has provided valid and robust practical insights on various issues. However, crafting a questionnaire that is applicable to the maritime domain is a challenging task due to the international nature and specificities of the sector. Although the questions reflect the spirit of the WEF executive opinion survey, the Maritime Country Profile survey is entirely different in wording, scope and intent. About 752 maritime professionals have participated in the survey. To date, about 704 submissions were considered as valid and about 564 country answers are complete. The range of professional positions occupied by the 489 respondents who submitted information to this extent varies from functional staff (14%) to senior executives (13%) and top executives (11%) as shown in Figure 4.1. About 30% represent their country internationally, such as the International Maritime Organization (IMO) or the International Labour Organization (ILO).

FIGURE 4.1 Participants positions




The survey was complemented with hard data from UNCTAD and the Seafarers Labour Force and Skills Survey used in the second chapter of this report (a complementary primary source). A final set of 82 sub-factors gauges the status of maritime technology adoption and development, using five factors to compute the overall composite score (see Annex E). The Country Profile scores were computed using data collected through the surveys in addition to hard data.

# 2 MARITIME COUNTRY PROFILE FACTORS AS A TOOL TO ASSESS COUNTRY READINESS

Five factors were used to assess the readiness of countries regarding the adoption of innovation and technology in the maritime sector.

## 2.1 TECHNOLOGY AND INNOVATION

The first factor is Technology and Innovation. Technology needs to be available on the market (Nerkar and Shane, 2007; Jarchow and Röhm, 2019). We have identified a wide variety of advanced technologies as representing significant technological trends. We have looked for the availability of Cloud computing, Big Data Analytics (BDA), Internet of Things (IoT), e-commerce, distributed ledger, Augmented Reality (AR) and Virtual Reality (VR), Artificial Intelligence (AI), industrial robots, autonomous ships, smart ships, remotely controlled ships, fleet monitoring centres, green ship equipment, green port equipment, and port automation. In addition, it is our assessment that the respondent businesses are active in implementing a set of comprehensive technologies: digitalization, ship automation and autonomy, ship digitalization, port automation and autonomy, port digitalization and supply chain digitalization. As in the previous version of the Country Profiles, the Technology and Innovation Environment is also considered. To achieve this, we have included six dimensions: new business models, innovation capacity, Research & Development (R&D), commercialization of ideas, disruptive business ideas and growth of innovative entrants. The breakdown of these factors is as follows:

### 1 TECHNOLOGY AND INNOVATION

#### 1.1 Technology availability (15 individual technologies)

- Cloud computing
- Big Data Analytics
- Internet of Things
- E-commerce and digital trade
- Distributed ledge technology
- Augmented and Virtual Reality
- Artificial Intelligence
- Industrial robots and drones
- Fully autonomous ships
- Smart ships
- Remotely controlled ships
- Fleet monitoring centres
- Green retrofitting of ships
- Green retrofitting of port super/infrastructure
- Port automation

#### 1.2 Technology business activeness (6 broad maritime technologies)

- Digitalization enabling technologies
- Ship automation and autonomy enabling technologies
- Ship digitalization enabling technologies
- Port automations and autonomy enabling technologies
- Port digitalization enabling technologies
- Supply chain digitalization enabling technologies

#### 1.3 Technology and Innovation Environment (6 factors)

- New business models
- Innovation capacity
- Research & Development
- Commercialization of ideas
- Disruptive business ideas
- Innovative entrants growth

## 2.2 LABOUR MARKET AND HUMAN CAPITAL

The second factor follows a similar approach to the previous version of the Country Profiles but refines and extends it to include labour market factors. As was previously the case, the human capital component is pivotal due to its importance as a facilitator of technology adoption (e.g. Romer 1990, Eaton & Kortum 1999, Hanushek & Kimko 2000, Krueger & Lindahl 2001). This factor includes education and training, skills availability (seafarers and onshore maritime personnel), labour market policies, gender and youth. The final set of factors is as follows:

**2 LABOUR MARKET AND HUMAN CAPITAL**

**2.1 Education and training (5 factors on education and training)**

**2.2 Skills availability: non-seafarers (2 factors)**

**2.3 Skills availability: seafarers (5 factors on skills, seafarers supply)**

**2.4 Labour market policies (6 factors on contracts, opportunities, labour-relation and talent retention)**

**2.5 Gender equality (2 factors)**

**2.6 Youth (2 factors)**

## 2.3 ECONOMICS AND BUSINESS

The third factor is Economics and Business, which reflects a similar spirit to the previous version of the Country Profiles but with an extended scope. To gauge this factor, we have studied the following factors: competitive environment, infrastructure and investment. The competitive environment is based on Porter's 5 Forces model in which suppliers and clients pressure the industry to compete. The degree of competition is measured by its concentration, the nature of the competitive advantage (value-added or labour costs), domestic control, and finally, supply chain integration within the maritime sector. Infrastructure covers the technological sophistication, quality and environmental sustainability of the industry. Finally, investment is assessed by the growth of innovative entrants and by accessibility to private and public funding. The factor is composed as follows:

**3 ECONOMICS AND BUSINESS**

**3.1 Competitive environment (6 factors)**

**3.2 Infrastructure (3 factors)**

**3.3 Investment (3 factors)**

## 2.4 SOCIAL ACCEPTANCE

Social Acceptance is the fourth factor, which was not featured in the previous Country Profile survey. In this version, we measure social acceptance by a combination of employee participation metrics and societal drivers. Participation of workers in technology is thought to benefit performance, working conditions and the promotion of better labour relations.[3] The factor follows a similar approach to that of the workplace,[b] which we augment by including general societal acceptance of disruptive technology. The stringency of environmental and technology regulations completes the factors driven by societal concerns as follows:

**4 SOCIAL ACCEPTANCE**

**4.1 Employee participation (5 factors)**

**4.2 Societal drivers (2 factors)**

## 2.5 REGULATION AND GOVERNANCE

The fourth and last factor is regulation and governance, which was already part of the previous version of the Country Profiles. The context in which technology is adopted and develops is influenced but the whole regulatory framework and its implementation, along with a broad governance setting.[1,4] The first element in the indicator relates to the technology-driven policy, which studies whether plans for adopting technology (including autonomous ships and digitalization) and its use by public authorities is in place. The second element covers regulation related to technology and the environment along with its enforcement. The final aspect is the importance of the maritime industry in the country. This sub-factor is compiled using hard data factors from secondary sources (shipbuilding, fleet ownership, size of the flag State and container port throughput). These newly developed factors provide greater scope and detail than offered by the previous Country Profiles, adding another layer of information. The factor is structured as follows:

[b] See https://workplaceinnovation.eu/

5 REGULATION AND GOVERNANCE

- 5.1 Technology-driven policy (5 factors)
- 5.2 Regulation (5 factors)
- 5.3 Maritime importance (5 factors)

FIGURE 4.2 Maritime Country Profile Analytical Model

# 3 FINDINGS

The analysis of the Maritime Country Profiles, based on an online survey (Maritime Leaders Opinion Survey), focuses on the five "macro-sections": Technology, Labour Market and Human Capital, Economics, Social Acceptance, and Regulation and Governance.

### SELECTED COUNTRIES:

**Africa:** Nigeria, Ghana, Kenya, South Africa, Egypt

**Americas:** Chile, USA

**East Asia and the Pacific:** Philippines, Indonesia, India, Bangladesh, Viet Nam, China, Republic of Korea, Sri Lanka, Japan, Myanmar, Singapore, Thailand

**Europe:** UK, Germany, Sweden

**Middle East:** Iran

### THE KEY FINDINGS ARE:

1. Clear challenges in developing and implementing technological and innovation measures and lack of identification of appropriate business models in the maritime sector.

2. Most countries have not implemented a proper incentive mechanism for the improvement of infrastructures and their competitiveness.

3. Favourable trend of Social Acceptance and regulation governance for developing countries

4. Positive trend within the Labour Market and Human Capital field

5. Promising gradual trend in reducing the gap between developed and developing countries in the maritime sectors

## 3.1 CLEAR CHALLENGES IN DEVELOPING AND IMPLEMENTING TECHNOLOGICAL AND INNOVATION MEASURES AND LACK OF IDENTIFICATION OF APPROPRIATE BUSINESS MODELS IN THE MARITIME SECTOR

The Technology and Innovation Environment Indicator Analysis demonstrates a lack of mature readiness for Innovation, Technology Feasibility and Technology Business Activeness.

The overall results of this indicator show the difficulties faced by the respondent countries in implementing the technological aspects in the maritime sector, not only in terms of implementing available technological tools but also in terms of developing the innovation context that could facilitate their implementation. Moreover, the economic and financial aspects affecting this factor, and the general lack of investments and risk and/or choice of business models, make technological improvement a challenge.

The selected countries are grouped into three categories based on their factor score: Leading (greater than 5.00), Good Potential (between 3.00 and 5.00), and Developing Countries (less than 3.00).

### LEADING COUNTRIES

The Republic of Korea is the only country that can be included in this group. The nation shows a positive trend in terms of Technology Feasibilities (and Technology Business Activeness. It seems that less effort has been invested in the Technology and Innovation Environment. From the results, it appears that the Republic of Korea gives priority to the technology field.

### GOOD POTENTIAL COUNTRIES

A total of 21 countries reached a score between 3.00 and 5.00. Five of them achieved above 4 (China, Sweden, Japan, United Kingdom of Great Britain and Northern Ireland, and Singapore), while the remaining 15 arrived at a score between 3.00 and 4.00 (Germany, Indonesia, United States of America, India, Ghana, Chile, Kenya, Viet Nam, Egypt, Nigeria, Islamic Republic of Iran, Sri Lanka, Thailand, Philippines, South Africa, Bangladesh). Despite the flattening of values, almost half of the countries reached more than 3.50 (i.e. middle score). Moreover, this block includes three developing countries: Indonesia, Ghana and India. Although the block lacks maturity in terms of technology, the trend is good for almost half the countries in that group. In terms of the Technology and Innovation Environment, Japan is the group leader with a score of 5.10, the United Kingdom of Great Britain and Northern Ireland, China, Germany and Sweden arrived at a value of over 4.00.

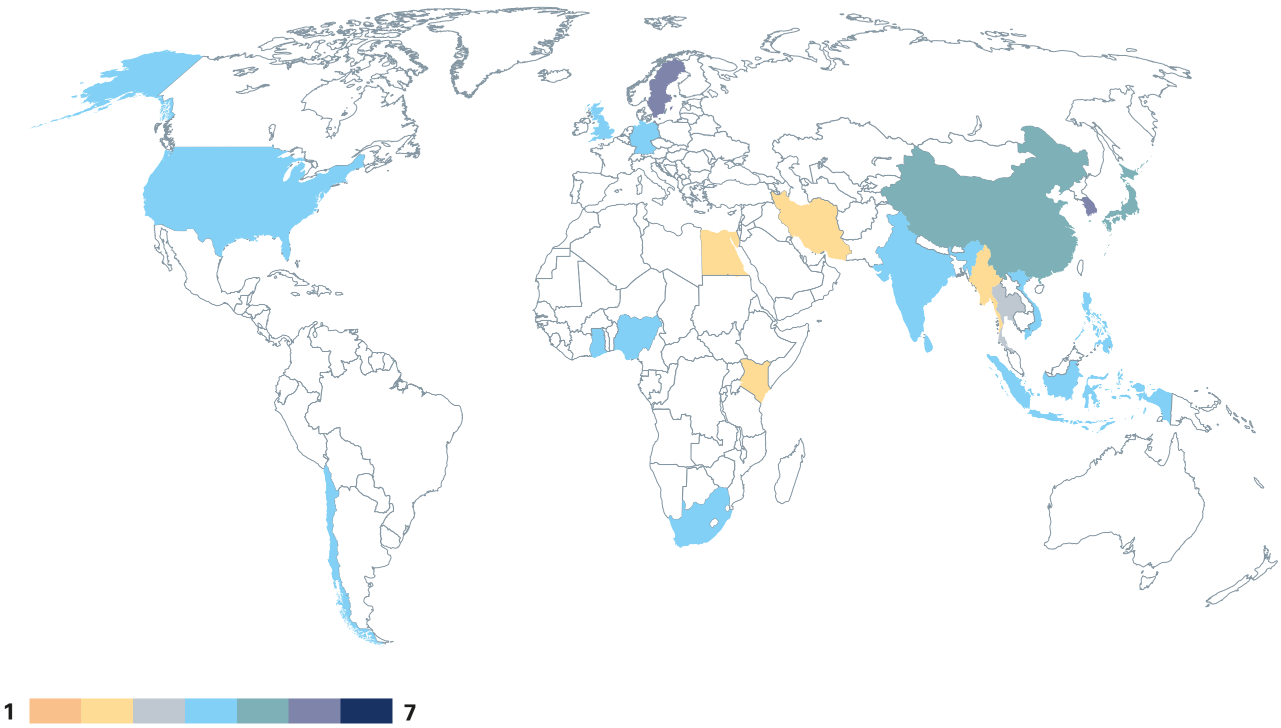
On the opposite scale, countries such as the Philippines, Bangladesh, South Africa, Sri Lanka, and Thailand registered a score under 3 in the Technological Feasibility sub-factor. Likewise, the Philippines, Bangladesh, South Africa, and Islamic Republic of Iran achieved below 3.00 in the Technology Business Activeness sub-factor. This tendency illustrates that these countries do not give priority to the technology field. Despite this negative trend, all countries in the Good Potential group achieved a score of more than 3.00 for their

Technology and Innovation Environment, which shows that they are adopting strategies that aim to innovate the sector.

### DEVELOPING COUNTRIES

Despite its negative Technology value, Myanmar registered a similar trend as the previous group: a higher score tendency for the Technology and Innovation Environment sub-factor and a lower score tendency in Technology Business Activeness and for Technological Feasibility.

FIGURE 4.3 Technology and Innovation factor values




## 3.2 MOST COUNTRIES HAVE NOT IMPLEMENTED A PROPER INCENTIVE MECHANISM TO IMPROVE INFRASTRUCTURES AND THEIR COMPETITIVENESS

The Economy and Business factor evidenced a flatting of the values, with a minimum of 2.80 and a maximum of 5.00. This trend demonstrates the "economic and financial challenges", the need to implement economic incentives to facilitate the maritime sector's investments at different levels, and finally the need to improve competitiveness and infrastructure.

Due to the general lack of high scores, the countries have been grouped into two categories based on their indicator scores: Good Potential (between 3.00 and 5.00) and Developing Countries (less than 3.00).

### GOOD POTENTIAL COUNTRIES

Twenty-two countries present an Economy and Business factor value between 3.50 and 4.90. In particular, 13 countries (Republic of Korea, Germany, Sweden, Philippines, United Kingdom of Great Britain and Northern Ireland, Japan, Chile, China, Singapore, Indonesia, India, Vietnam, United States of America) registered a score over 4.00. The remaining nine countries (Islamic Republic of Iran, Bangladesh, Sri Lanka, Kenya, Egypt, Thailand, Ghana, South Africa, Nigeria) reached between 3.46 and 3.99.

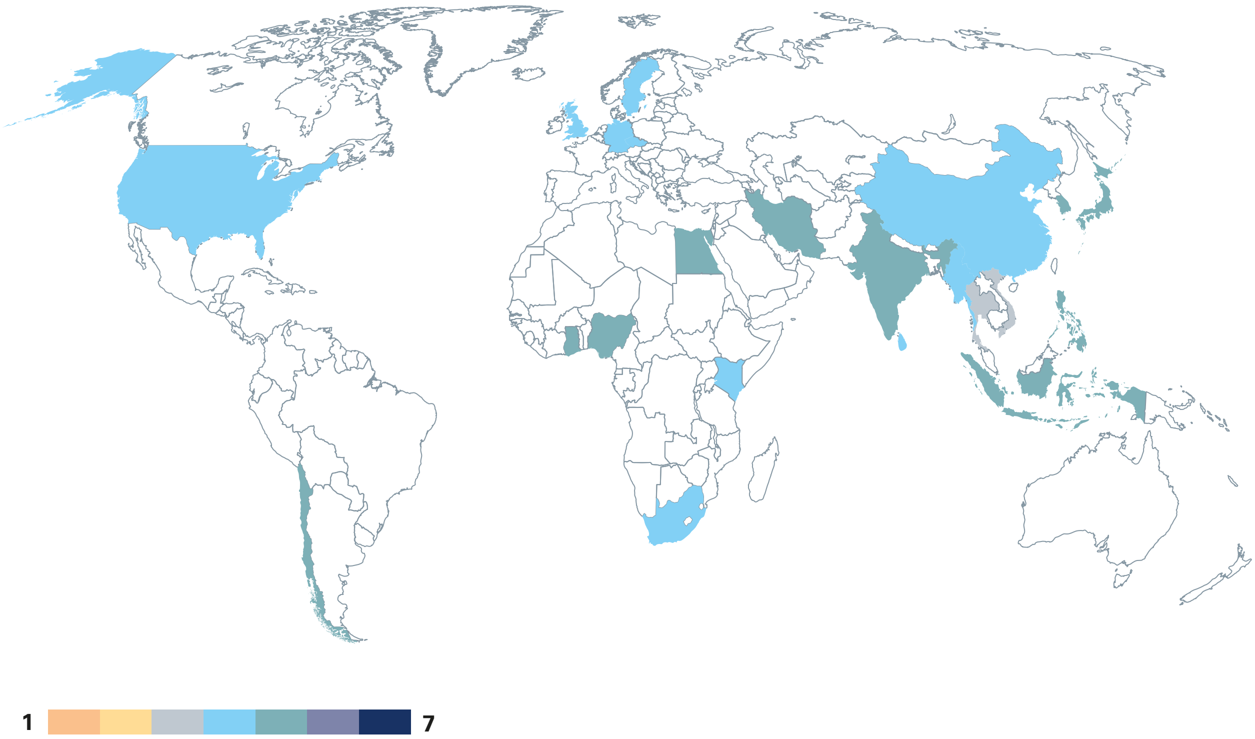
Regarding the Competitive environment, the registered scores rank between 4.90 and 3.50. This demonstrates a lack of competitiveness in the different countries. There is a similar trend for the Infrastructure and Investment sub-factors, where scores range between 3.70-4.70 and 3.00-4.70, respectively.

Overall, there is a need for all the above-mentioned countries to facilitate the development and implementation of investment plans and improve their logistics infrastructures.

### DEVELOPING COUNTRIES

Myanmar is the only country that scored an Economy and Business factor value under 3.00. It reached a score close to 3.00 for the Competitive environment and Investment sub-factors. However, the nation scored 2.40 for Infrastructure. Also in this case is there a need for planning strategies for the economy and business sector.

FIGURE 4.4 Economics factor values




## 3.3 FAVOURABLE TREND OF SOCIAL ACCEPTANCE AND REGULATION GOVERNANCE FOR DEVELOPING COUNTRIES

The analysis illustrates a favourable trend for Social Acceptance in developing countries; the minimum value was 2.90, the maximum value was 4.30. This factor reflects the difficulty of dealing with the human factor, which is evident in the scores for employee participation and social drivers in developing countries not being ranked very differently than those of developed ones. Gathering input from the different maritime stakeholders is crucial to guide policymakers and improve social factors.

There is a similar trend in the Regulation and Governance factor, with a range for developing countries between 2.50 and 4.20 and the maximum value for developed countries of 5.60.

One of the main outputs from the respondent countries is the increased effort to invest more in technology-driven policies and regulations rather than maritime policies. This illustrates that the maritime sector is still not a priority, which is a general trend in various contexts in developed and developing countries and around the world. Evidently, there is a clear need for greater emphasis on legislation in the maritime field, especially for goods and passengers.

FIGURE 4.5 Social Acceptance factor values

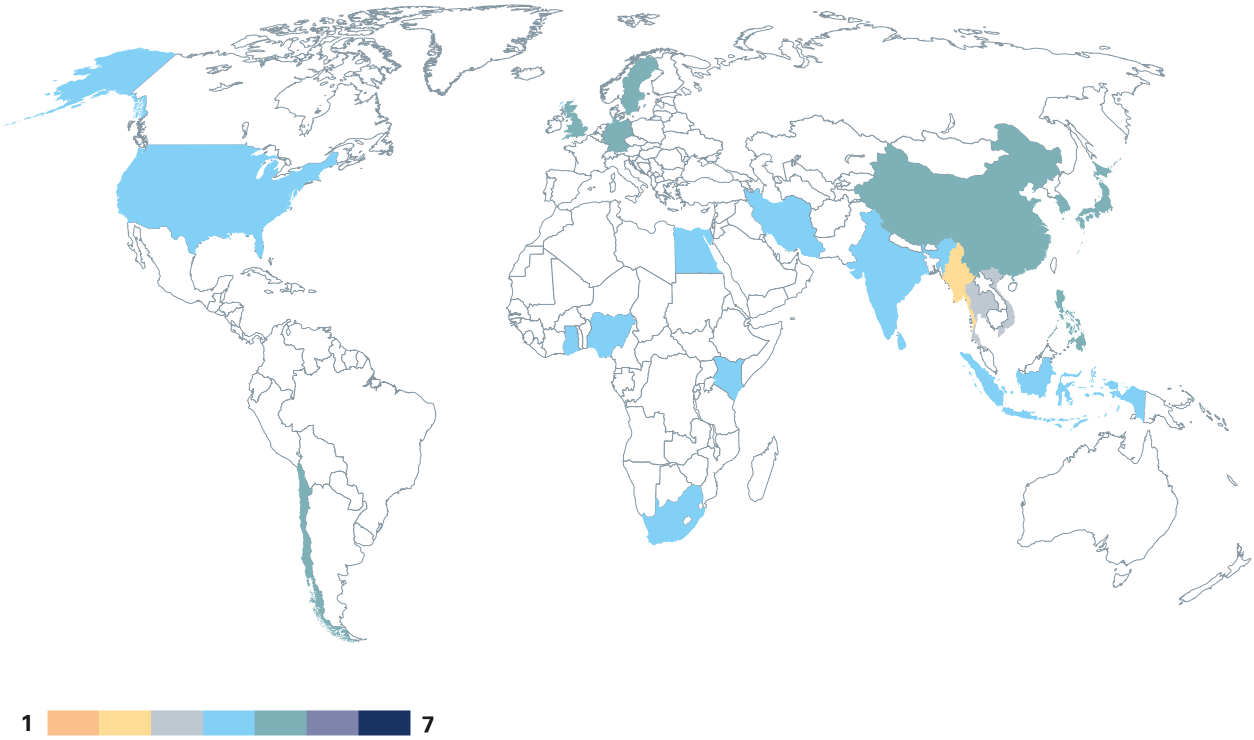
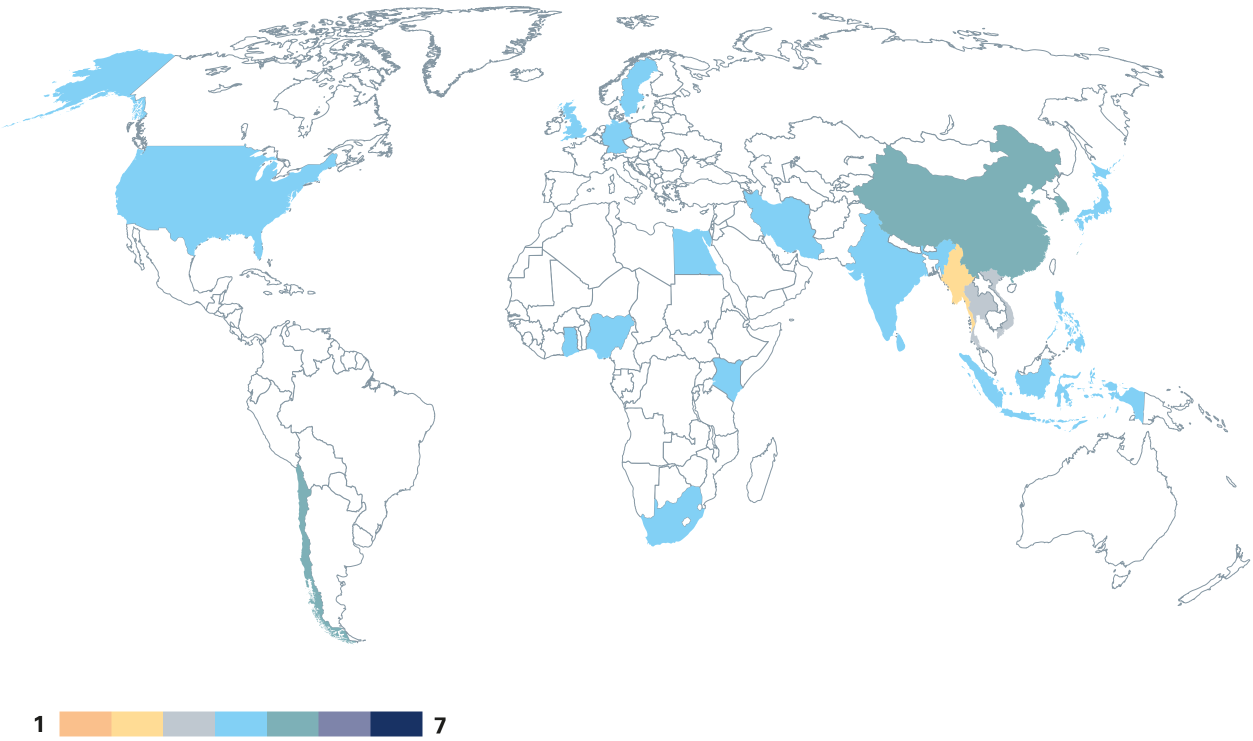



FIGURE 4.6 Regulation and Governance factor values



With these two indicators, the countries are grouped into two main categories: Developing Countries (15) and Developed Countries (8):

### DEVELOPING COUNTRIES

The Developing Countries are Nigeria, Philippines, Indonesia, India, Ghana, Bangladesh, Kenya, Viet Nam, South Africa, Sri Lanka, Egypt, Chile, Thailand, Islamic Republic of Iran, and Myanmar.

In terms of Social Acceptance, for the Employee Participation sub-factor, only three countries scored over 4.00 (the Philippines, Indonesia, Viet Nam) and only one under 3.00 (Myanmar). The Societal drivers show a similar trend with three countries achieving over 4.00 (Chile, Viet Nam, Thailand) and only one under 3.00 (Myanmar). There is a tendency towards incremental involvement of internal and external stakeholders.

In the Regulation and Governance factor, for the Technology-driven policy sub-factor, eight countries (the Philippines, Indonesia, India, Bangladesh, Kenya, Viet Nam, Chile, and the Republic of Iran) reached a score over 4.00. With Regulation, six countries scored over 4.00 (the Philippines, India, Bangladesh, Viet Nam, Chile, and the Republic of Iran), for Maritime importance only Indonesia reached a score over 4.00. Within all three sub-factors, only Myanmar achieved a value under 3.00. The results illustrate that these countries are currently in the phase of developing regulations and technology-driven policies, although not focused on the maritime domain.

### DEVELOPED COUNTRIES

The selected developed countries are the United Kingdom of Great Britain and Northern Ireland, China, Korea, Japan, the United States of America, Germany, Singapore, and Sweden.

With the Social Acceptance factor, the Employee Participation sub-factor shows that only three countries reached a score over 4.00 (China, Japan, Sweden), and with Societal drivers, six countries reached over 4.00 (United Kingdom of Great Britain and Northern Ireland, China, Japan, Germany, Singapore and Sweden). An important highlight of this finding is the tendency of incremental efforts in involving internal and external stakeholders. In terms of employee participation, less than half of the countries in the group obtained a great score. However, there is a better trend for the Societal drivers.

In terms of the Regulation and Governance factor, for the Technology-driven policy sub-factor, four countries (United Kingdom of Great Britain and Northern Ireland, China, Japan, and Germany) achieved a score over 4.00. For the Regulation factor, six countries scored a value over 4.00 (United Kingdom of Great Britain and Northern Ireland, China, Japan, Germany, Singapore, and Sweden), for Maritime importance only China and Japan reached a score over 4.00.

## 3.4 POSITIVE TREND IN THE LABOUR MARKET AND HUMAN CAPITAL FIELD

Despite no examples of excellent cases in the Labour Market and Human Capital factor, respondent countries show a positive tendency with a minimum score of 3.6.

For Education and skills availability (seafarers and non-seafarers), the average value is 4.50, which illustrates a positive trend regarding qualified personnel, including a proper training programme. For Labour market policies, the values range between 3.70 and 4.70, showing a good but somewhat stagnant situation. All the respondent countries should aim to increase labour relations and talent retention. Concerning gender equality and youth, most selected countries present low scores, which reflects the tendency in the maritime sector to employ senior personnel with a consequently higher quality of experience, yet low score in gender balance.

The countries have been grouped into two categories based on their indicator score: Leading (more than 5), and Good Potential countries (between 3 and 5).

### LEADING COUNTRIES

The leading country is the Philippines. It registered positive values for Education and training, Skills availability for seafarers and Youth opportunity. On the other hand, with the Skills availability for non-seafarers, Labour market policies, and Gender equality sub-factors, the average score value is under 5.00. The results show an overall positive trend. However, gender equality remains an area that needs improvement.

### GOOD POTENTIAL COUNTRIES

The 22 remaining countries scored between 3.50 and 5.00. In particular, 13 countries (India, Republic of Korea, Indonesia, Egypt, Ghana, Bangladesh, Islamic Republic of Iran, Chile, United Kingdom of Great Britain and Northern Ireland) ranked between 3.5 and 4.00. Nine selected countries reached a score between 4.00 and 5.00 (Nigeria, Myanmar, Kenya, Viet Nam, United States of America, Germany, Singapore, South Africa, China, Sweden, Japan, Sri Lanka, Thailand).

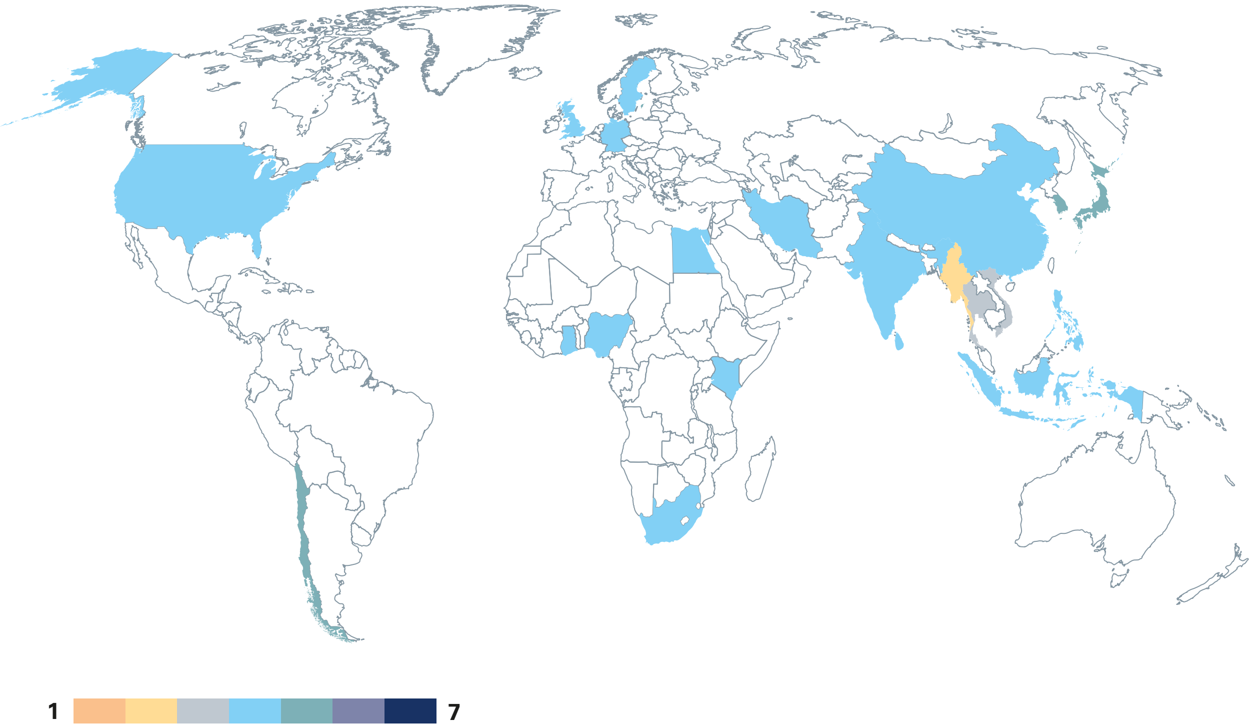
For the Education and training, Skills availability for seafarers, and Skills availability for non-seafarers' sub-factors, the results show a positive trend. All the selected countries reached a score over 3.40, with a few achieving a score over 5.00. Overall, the general trend highlights a positive tendency in improving skills for the sector.

The Labour market policies' sub-factor illustrates a flatter trend with values between 3.50 and 4.80. The respondent results show a lack of ad hoc incentives to improve and upgrade relevant Labour market policies.

A fluctuating negative trend for the Youth sub-factor, with only one value reaching over 5.00 and three under 2.80. The remaining values are between 3.00 and 4.80. Nonetheless, it is essential to highlight that some Good Potential countries are open to employing young workers, although the general tendency is to prefer to invest in senior professionals.

The most significant result is Gender equality where only two values reach above 4.00 and where three are registered under 2.70. The remaining ranks are between 3.00 and 4.00.

FIGURE 4.7 Labour Market and Human Capital factor values




## 3.5 PROMISING GRADUAL TREND IN REDUCING THE GAP BETWEEN DEVELOPED AND DEVELOPING COUNTRIES IN THE MARITIME SECTORS

Despite the existing clear gap between developed and developing countries, the numerical values show a positive trend for reducing the disparity in terms of technology, market and human capital, economy, social acceptance, government and regulation.

The general tendency shows that the Republic of Korea has achieved a better state-of-the-art than other countries in terms of Technology, Economy and Business, Social Acceptance, Regulation and Governance. The Philippines achieved a higher score in Labour Market and Human Capital than other countries. The initial analysis is that all respondent countries need to implement strategies in the indicators sectors, as previously reported. Better cooperation between developed countries could stimulate the creation of Innovative Technology Initiatives (ITECH), providing economic incentives for the improvement of R&D in different aspects of the maritime sector.

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CHAPTER 5

# COUNTRY REPORTS:

## IMPACT OF TECHNOLOGY ON OCCUPATIONAL SAFETY AND HEALTH OF SEAFARERS

5

(Photo credit: Aljon Manlangit, reprinted with kind permission of ©ITF Seafarers' Trust. )

**Author:** Khanssa Lagdami

COUNTRY REPORT – AUSTRALIA

# AI & BIG DATA AT SEA

## EXPLORING THE POTENTIAL RISK OF SURVEILLANCE OF SEAFARERS

# 5.1

(Photo credit: Shutterstock and Aljon Manlangit)

# 1 EXECUTIVE SUMMARY

Despite an increase in academic research exploring surveillance of employees by their employers, the topic of surveillance practices at sea regarding seafarers is seldom addressed. Surveillance can affect the working conditions of seafarers, who are guaranteed functional autonomy in a very particular working environment where the division between private and work life is blurred. AI, big data and algorithms at sea are some of the tools that raise questions regarding the monitoring and control of seafarers at sea as well as the impact of such surveillance on the Occupational Safety and Health (OSH) of seafarers.

This chapter focuses on the Voyage Data Recorder (VDR) as an example of monitoring devices used on vessels and examines the international legal requirements for its application. The Australian legal framework is taken as an example. In addition, practical points of view are added based on interviews with practitioners and technology developers.

Based on the analysis presented, the report identifies four areas for responding to the challenges raised by the use of AI and big data on vessels:

| | |
|---|---|
| 1 | Ensure that seafarers retain ownership and control over data about them generated while serving on board; |
| 2 | Data on seafarers generated while serving on board should be used for the sole purposes of security and safety; |
| 3 | International legislation should be adopted governing the uses of AI and big data on board vessels that enshrines principles of responsibility for the impact of their use. The legislation should include the requirement to inform seafarers of the existence of any monitoring devices on board as well as where they are installed.; |
| 4 | Ensure the training of workers in the challenges of tomorrow. Seafarers should be made aware of the technical, legal, economic and ethical issues posed by the use of AI-based tools. |

# 2 INTRODUCTION

The emergence of the digital era has impacted work and the economy in such a way that tasks normally performed by humans are gradually being taken over entirely by machines.[1] Whereas Human Intelligence (HI) signifies the intellectual ability that enables humans to learn from various experiences, think, understand intricate concepts, apply reasoning and logic, solve mathematical problems, identify patterns, make decisions, hold on to information and communicate with fellow human beings,[2] Artificial Intelligence (AI), on the other hand, implies the creation of intelligent machines with the capability to imitate intelligent human behaviour.[3]

Some computers integrated with AI are designed to perform speech recognition, learning, planning and problem solving. AI differs from HI in relation to its nature, functioning and learning power.[4] While humans attempt to adapt to new environments by integrating several cognitive processes, AI seeks to digitally and mechanically imitate human behaviour and perform human-like actions. HI functions by using memory and the ability to think, compute, learn, and understand from various previous experiences. Machines powered by AI, on the other hand, depend on data and instructions fed into their systems by humans and therefore cannot think.[5] Indeed, AI technology is not yet able to function independently without some degree of human control. Although proven useful within the shipping industry – for instance with collision avoidance, and by offering the potential of substituting seafarers – AI technologies may, nonetheless, prove detrimental to the safety of shipping if human control were to be eliminated from AI systems entirely.[6]

AI relies on other technologies for its efficiency. The main underlying technologies that support AI include digitalization, the Internet of Things (IoT), big data and algorithms. Digitalization is the process of using digitized information to improve systems; the IoT connects physical objects to a network, such as sensors and cameras, thus simplifying digital data collection and transmission; and big data provides a means to process and analyse the data obtained from AI systems.[7]

Within shipping, the integration of AI and navigation systems requires the management of big data sourced from systems that support the navigation and/or machinery of a vessel as well as from related marine fleet management systems, which implies a need to manage this extensive body of data appropriately.[8] Indeed, the emerging domain of data management known as Big Data Analytics (BDA) is the result of the limitations of human intelligence in analysing big data. There is therefore a need for AI systems to examine large amounts of data to reveal patterns, correlations and interactions between different measurable or non-measurable parameters and thereby help organizations make informed decisions for business growth. BDA can be classified as a special branch of the wider Information Technology (IT) domain.[9] The current as well as future use of AI in the maritime industry is already referenced in the literature. Current uses in the maritime industry include tracking and surveillance, optimization, safety and cargo handling.[10]

Within the shipping industry, tracking and surveillance are processes that work in synergy to offer the potential of effectively supporting maritime safety and security. AI tracking and surveillance helps alert the bridge in the event of people falling overboard and furthermore assists in tracking passengers in emergencies, detecting illegal fishing, pirates and vessels in distress, stopping fires as soon as they start, and identifying stressed or fatigued crew members. AI optimization already helps the shipping industry to optimize fuel use, maintenance, operations, paperwork, port calls, logistics and voyage planning.

With the increase in regulatory and commercial pressure towards further optimization, AI applications will certainly be expanded in the future. Just as shipping has benefitted from previous innovation, each new development offers further benefits of either improved efficiency, safety or cost savings, or more environmentally friendly operations. Indeed, this was the case when Heavy Fuel Oil (HFO) and diesel replaced coal and when containers replaced crates, sacks and barrels. Moreover, safety among seafarers has already been enhanced by AI-driven robots taking over high-risk tasks, ranging from tank entry to underwater hull inspection. AI drones are also used for hold, hull and tank inspections, thereby saving time and money. Furthermore, AI helps to identify cargo in containers that requires being declared before loading, thus preventing container fires and improving safety.[11]

Although AI has been successfully embraced by the shipping industry, its impact on the future working conditions and surveillance of seafarers is still being questioned. Researchers have argued that the effects of AI on growth and employment are more complex than generally recognized by societies and that the impact will depend on the institutional and policy environment this technology is offered.[12] While some researchers maintain that the work of seafarers may change due to the emergence of autonomous ships,[13] others argue that the AI revolution will not necessarily impact employment negatively. Indeed, automation appears to offer positive benefits in terms of new opportunities for skilled labourers.[14]

This latter perception is supported by several studies, one of which was conducted by the Hamburg School of Business Administration (HSBA) on behalf of ICS. The study found that the emergence of autonomous ships is likely to redefine rather than terminate the role of seafarers, indicating that "there will be no shortage of jobs for seafarers, especially officers, in the next two decades. While the size of crew may evolve in response to technological changes on board, there may also be considerable additional jobs ashore which require seafaring experience".[15] Moreover, industrial plants that undergo automation are already experiencing increased employment, further suggesting that existing labour market perceptions of a negative correlation between automation and aggregate employment only highlight the importance of employment training and adopting national policies when seeking to determine the real effect of automation on aggregate employment.[16]

The above discussion may arguably reflect the apparent positive impact of AI in the maritime industry. What remains to be studied, however, is how big data and algorithms related to AI systems on board ships may be negatively exploited, especially in terms of the surveillance of seafarers. Since AI use on ships is still in its infancy, this report will focus on the use of big data in the maritime industry and how such technology can potentially be exploited for the surveillance of seafarers. The report also examines the legal aspects governing the processing of such data and their implications for the maritime industry. The report furthermore studies the example of the Voyage Data Recorder (VDR), which is considered a ship's black box. The international legal requirements on the use of data obtained from a VDR are examined in context with an Australian case study.

# 3 ETHICAL CONCERNS ON THE USE OF AI, BIG DATA AND ALGORITHMS FOR THE MANAGEMENT OF EMPLOYEES

Until recently, the efficiency of employee work output was monitored by setting Key Performance Indicators (KPIs). Assessments were conducted by the Human Resource Department, which is also responsible for employee recruitment, the preparation of employment contracts, and the management of employee/employee and employee/employer relationships. Digital technology is now used alongside analogue methods to assess work performance as well as other aspects of the role of human resources. New and emerging technologies furthermore offer the potential of being exploited as surveillance tools due to any kind of surveillance equipment at a workplace being a manifestation of the employer's executive power. Such surveillance equipment facilitates giving direct orders and instructions to employees as well as assessing and monitoring the work performance and capabilities of individuals with the aim of either offering promotion or deciding on the termination of a work contract. Indeed, the use of AI, big data and algorithms at workplaces has substantially transformed the employment relationship.

A study has noted that globally about 40% of human resource duties in some small and large companies are conducted using AI-augmented applications for workforce management.[17] These systems are integrated with technologies that offer the ability to track personal information about workers, such as their sentiments, physical movement, social media use and other activities over time, thus generating huge amounts of data, known as big data, used to monitor work efficiency.

How this personal data is stored and used by management is a cause for concern.[18] For instance, People Analytics (PA) is a Human Resources (HR) practice whereby big data and digital tools are used to "measure, report, and understand employee performance, aspects of workforce planning, talent management, and operational management".[19] Studies have shown that around 71% of international companies are considering giving high priority to PA, which in addition to providing good insight into overall business operations also addresses conventional employee issues, such as Occupational Safety and Health (OSH), talent management, employee ethics, employee relations, business continuity and reputational risks.[20]

(Photo credit: Heigh-ho)

# 4 OCCUPATIONAL SAFETY AND HEALTH (OSH) RISKS POSED BY MONITORING TECHNOLOGY

Several research studies have linked electronic monitoring to working conditions, encompassing multiple aspects such as work performance, worktime, work rhythm, cooperation between employees and employers, skills development and employee wellbeing.

Human capital management and performance management are two major HR roles that have been enhanced by AI, although with repercussions for worker OSH. PA tools are known to be used in the HR recruitment process to help make good decisions about employees even before they are hired, provided relevant data can be accessed and obtained. Additionally, some tools allow employers to carry out interviews on camera to curb certain forms of bias during interviews.

AI tools also have the capacity to compare worker performance with performance pay to enable the development of business strategies for individual workers. However, such algorithmic decision-making tools have demonstrated a high probability of causing OSH related issues, such as heightened structural, physical and psychosocial risks and stress, unless employers ensure human intervention and embrace ethical considerations.[21]

Workers may arguably call into doubt the fairness, honesty and accuracy of decisions made by their employers (such as job displacement and workplace restructuring) due to not having access to the PA data on which their employers base their decisions, which may lead to stress and anxiety. Workers may also sometimes feel they are being "spied upon" if they perceive that the PA data is being used for performance management without due diligence. In organizations where performance management outcomes lead to layoffs, workers may also feel under obligation to enhance their performance and overwork themselves for fear of losing their jobs, which may in turn result in OSH issues. Indeed, most labour issues arising from the use of AI at workplaces relate to the use of PA to collect workers' data for decision-making.

Other workplace AI systems that have been the cause of OSH issues include cobots and chatbots. AI-enhanced tools have in these cases been incorporated into several industrial processes, which has resulted in the risk of psychosocial stress related to the fear of losing jobs to bots. Several industries, such as car manufacturers, use cobots to undertake tasks that would have taken humans longer to perform. Not only have human hands have been replaced by robotic hands, AI has also enhanced robotics so robots can think much like humans and thereby replace the human brain.[22]

While one report has indicated that the use of cobots has reduced OHS risks by mitigating worker exposure to hazardous ergonomic and physical conditions as well as chemical-heavy work environments, another study has identified three main types of OHS issues ensuing from human/cobot/environment interactions. They include:

1. Robot/human collision risks due to unpredictable robot behaviour caused by machine learning;

2. Security risks in which the robot's Internet link can tamper with the integrity of the software programming and render the system vulnerable to security threats; and

3. Environmental risks in which unpredictable human action and sensor degradation in unstructured environments can result in environmental risks.[23]

Furthermore, AI technology has enabled voice recognition and machine vision to be integrated into chatbots. This is thought to place both unskilled and skilled jobs at risk of extinction since more jobs are likely in the future to be performed by machines rather than humans. For instance, a chemical company that produces optical accessories for machines once required one person to sit for extensive hours in front of repeated visual scans of miniscule machine chips to identify errors. AI has now replaced the workers in executing this task, leading to the elimination of such OSH risks as musculoskeletal difficulties, and eye strain and damage.

Nevertheless, AI-augmented robots at such factory plants can cause stress among workers when not properly applied. When integrated at a workplace, automation, algorithmic management and digitalization can cause psychosocial stress, especially when workers are expected to perform at the pace of robots rather than robots working at a human pace. One worker may be expected to monitor a machine that sends notifications to their personal electronic device, such as a smartphone or personal computer. This feed of notifications may lead to psychosocial issues, such as work overload where workers continue working beyond hours.

# 5 MONITORING WORKERS AT SEA

**CAN WORKERS AT SEA BE MONITORED THE SAME WAY AS WORKERS ON LAND?**

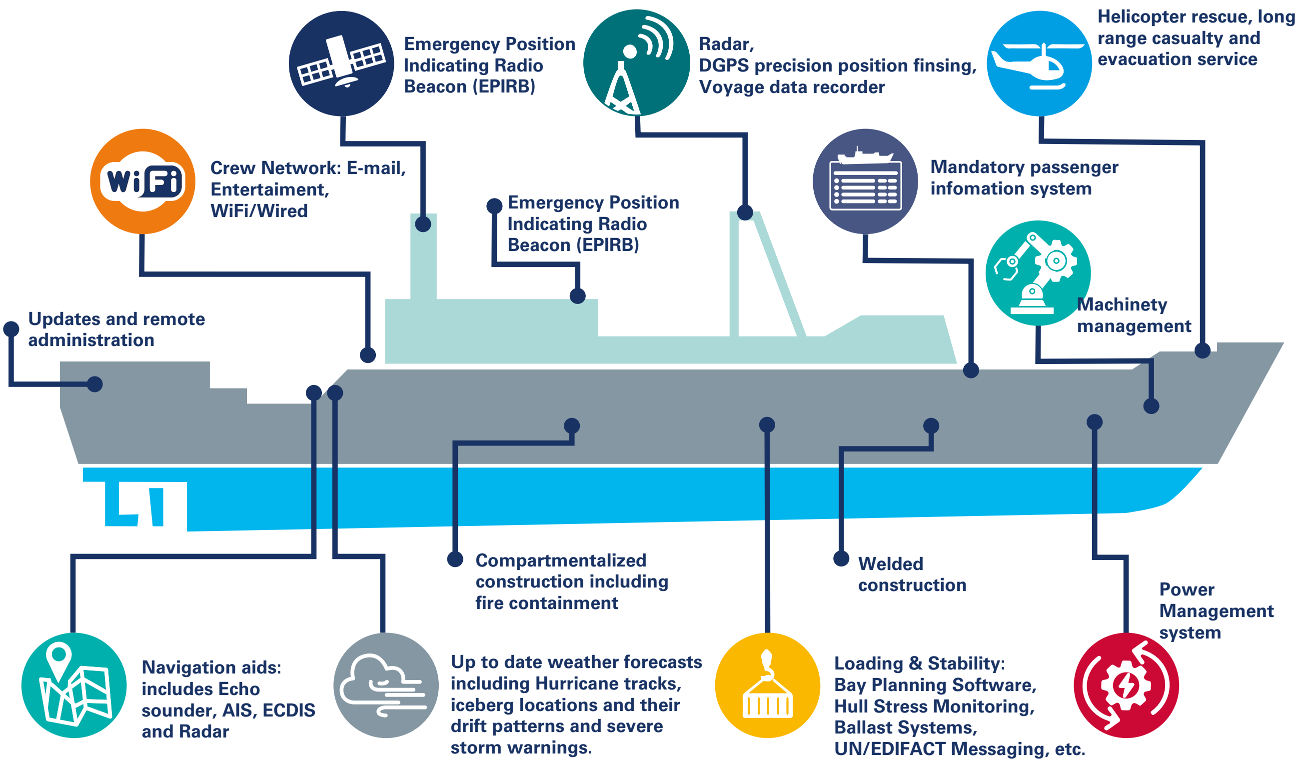
The answer to this question is unquestionably negative since seafaring has no clear division between professional and private life and, subsequently, requires different risk prevention practices since life at sea is also intrinsically more accident-prone.

Ships are restricted in their space and exposed to the dangers of navigation. Work on board is not only affected by the risk of accidents but also by limitations in mobility and isolation. Life on board, where work and rest take place within the same confines, requires a focus on work management as well as on the composition and size of the crew. Improving onboard working conditions includes addressing the living conditions as well as the safety of life at sea.

Surveillance is not only a question of enhancing security on board but also one of subordination, ensuring the crew follows the orders and instructions issued by the shipowner. Surveillance measures may therefore serve several objectives, including safety, security, implementation of regulation, and the enhancement of commercial operations. The monitoring of a ship and its crew is furthermore bound by obligations of the shipowner to adhere to the international conventions of the International Maritime Organization (IMO), of the International Labour Organization (ILO), such as the Safety of Life at Sea Convention, the ISPS Code, the 2006 Maritime Labour Convention (MLC 2006) or the Convention on Work in Fishing Convention (C188).

Employers justify the installation of surveillance tools with reference to the requirement of monitoring safety or hygiene. Still, such tools may also restrict fundamental rights, including the protection of the integrity and private life of an employee. The monitoring of employees, whether land-based or at sea, pursues the multiple objectives of surveillance, work activity safety, and commercial business. Technological development has helped enhance the availability of digital, acoustic, electronic and optical tools, such as video systems, geolocation, spyware, sensor devices, and the recording of conversations. However, work at sea inevitably differs from land-based activity since no other industry requires its employees to continuously be present in the workplace with the specific duty of ensuring the safety of their mobile workplace as well as the cargo and crew on board.

FIGURE 5.1.1 Automation systems for modern and autonomous ships




Source: CruisMapper.[24]

Can workers at sea be monitored the same way as workers on land? The answer to this question is unquestionably negative since seafaring has no clear division between professional and private life and, subsequently, requires different risk prevention practices since life at sea is also intrinsically more accident-prone. Monitoring devices should therefore fulfil specific requirements. The reconciliation of the professional and private lives of seafarers cannot be approached in the same way as land-based workers, since the workplace is mobile and operates in a non-natural environment for humans.

No doubt, the use of monitoring devices represents a response to the professional needs of both the employer and their crew. However, the consequences of using data collected through a monitoring system can be very significant. The collected data can provide evidence or visual proof of an accident that may constitute the basis for sanctions or dismissal. Nevertheless, depending on the practices and policies of individual companies, the same collected data may also be used to assess the work environment. While there is currently no clear evidence of surveillance data regarding seafarers being exploited by shipowners, the streamlining of work processes should strive to balance the interest of shipowners with workers' rights.

That no laws cover the collection of data from CCTV surveillance on ships, such as systems installed on deck used to prevent illegal acts at sea, is apparent despite employees already having been informed of such systems on board.[25]

Onboard surveillance and monitoring devices have several different risk prevention purposes. However, data collected from surveillance may also be used for disciplinary purposes or to settle disputes, which are purposes far removed from the enhancement of worker safety.

International and national regulation related to the protection of employee data is still in its early stages of development. In the maritime industry, such regulation is almost absent. It is still common for the interests of a company to take precedence over the protection of workers, as exemplified by the many cases where work performance has been recorded by audio or video equipment.

# 6 THE CASE OF THE VESSEL DATA RECORDER (VDR)

According to the International Maritime Organization (IMO), the Vessel Data Recorder (VDR) is a complete system, including any items required to interface with the sources of input signals, their processing and encoding, the final recording medium, the playback equipment, the power supply and the dedicated reserve power source. A VDR is generally considered to be the ship's "black box" since it gathers and stores various types of information during its voyage. This may include the ship's location, audio from the bridge, speed, depth under the keel and VHF radio communications. IMO established the performance standards and specifications for VDRs in 1997, including standards for the data to be recorded. The VDR, according to these standards, is expected to work continuously to maintain sequential records of preselected data items regarding the status and output of the ship's equipment and command and control. Moreover, the VDR is expected to be installed in a brightly coloured protective capsule fitted with an appropriate device to aid location, and should be entirely automatic in normal operation.[26]

FIGURE 5.1.2 A Vessel Data Recorder


Source: Shutterstock

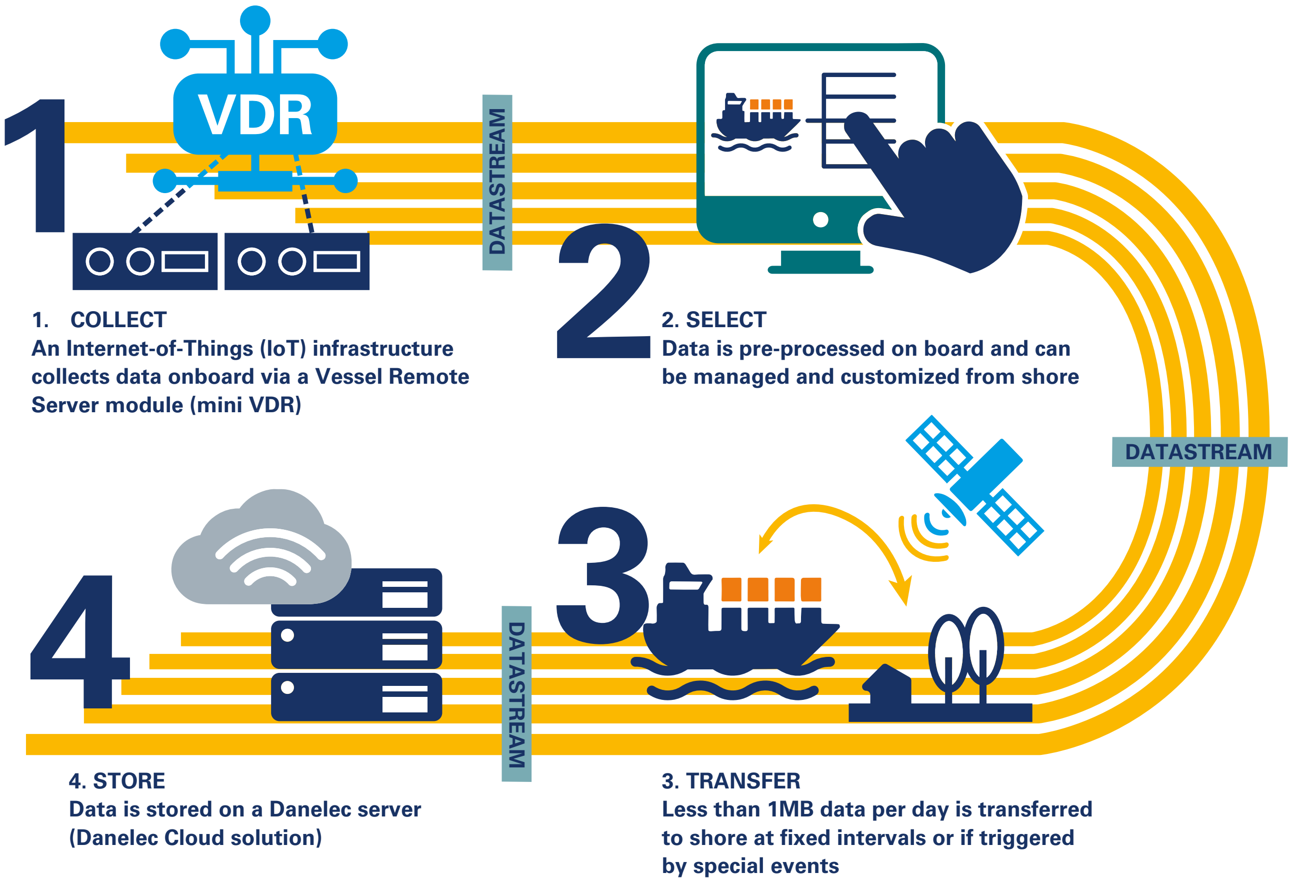
## 6.1 LEGAL REQUIREMENTS FOR THE INSTALLATION, ACCESS AND USE OF A VDR AND VDR DATA

Like with every industry, the implementation of new technologies requires legal standards, which will also entail legal and ethical challenges. Such is also the case with the use of AI. The shipping industry has seen the emergence and use of AI systems, and international regulations oblige some aspects of navigation to be integrated into AI systems. The use of VDR on board is, for instance, governed by the provisions of the International Convention on the Safety of Life at Sea (SOLAS 74).

FIGURE 5.1.3 VDR Requirements - New ships built after 1 July 2014


Source: Sean Payne[28]

FIGURE 5.1.4 An example of the VDR system installation




Source: Danelec, a Danish technology developer

Regulation 20 of SOLAS requires a VDR to be fitted in all passenger vessels and all cargo vessels of 3000 gross tons or more.

Furthermore, Regulation 18 of SOLAS chapter V on Approval, surveys and performance standards of navigational systems and equipment and voyage data recorder states that: "The voyage data recorder (VDR) system, including all sensors, shall be subjected to an annual performance test. The test shall be conducted by an approved testing or servicing facility to verify the accuracy, duration and recoverability of the recorded data. In addition, tests and inspections shall be conducted to determine the serviceability of all protective enclosures and devices fitted to aid location. A copy of the certificate of compliance issued by the testing facility, stating the date of compliance and the applicable performance standards, shall be retained on board the ship."

## 6.2 PROTECTION OF DATA STORED IN THE VDR

**GLOBALLY, VDR INFORMATION HAS REMAINED UNREGULATED DUE TO THE NON-EXISTENCE OF APPLICABLE NATIONAL REGULATIONS.**

The importance and protection of the data stored in the VDR has been highlighted by the IMO through its Maritime Safety Committee (MSC) which, according to the Organization, should be used during casualty investigations in accordance with the guidelines established by IMO (MSC/Cir.1204 of 29 May 2002) together with the Code for Investigation of Marine Casualties and Incidents (Resolution A.849(20) of 27 November 1997, also known as the Marine Casualties and Incidents Code (MCI Code).

The MCI Code contains mandatory and recommended standards regarding the use of VDR information, which include restrictions on the use of VDR information in legal proceedings as well as the obligation to have an independent investigative body. Section 5.1.5 of the MCI Code states that "Effective use should be made of all recorded data, including Voyage Data Recorders (VDR), if fitted, in the investigation of a marine casualty or marine incident wherever it occurred. The State conducting the investigation should arrange for the read-out of the VDR."

Section 10 also lists the type of information obtained during the conduct of the casualty investigation that is not permitted to be disclosed for purposes other than casualty investigation. Such information should be included in the final report only when pertinent to the analysis of the casualty or incident.

Moreover, the parts of the record not pertinent, and not included in the final report (which may also include the VDR information), should not be equally disclosed (Resolution A.849(20) of 27 November 1997). Additionally, the MSC adopted Resolution MSC 494 (104) on 7 October 2021 recommending that a VDRs' float-free recording medium should be installed in a float-free capsule, which shall: 1) maintain the recorded data for a period of at least six months following termination of recording; and 2) be capable of being accessed following an incident but secure against a physical or electronically manipulated change or deletion of recorded data. Prior to the adoption of this recommendation, the MSC established guidelines on VDR ownership and recovery (MSC/Circ. 1024 of 29 May 2002) which highlighted the importance of close coordination and co-operation among parties interested in the recovery of VDR information.

The IMO Circular provides guidance on the ownership, recovery, custody, read-out and access to the VDR information and relevant information. Recovery of the VDR depends on its accessibility or the availability of the information it contains, and this is expected to be carried out as soon as possible after an accident to preserve the relevant evidence in the most appropriate way for subsequent use by the investigator. The master of the vessel is charged with the responsibility to preserve the VDR information in case of vessel abandonment during an emergency, until it can be submitted to the investigator. If, prior to abandonment, the VDR is inaccessible and the information is irretrievable, the flag State, in collaboration with other substantially interested States, may establish or weigh the viability and cost of recovery against its potential use, and establish if it is absolutely necessary to pursue and recover the VDR information. Other stakeholders such as the shipowners, insurers, manufacturers of both the VDR and its protective capsule, may be required to assist and cooperate in the recovery process.

Moreover, in the course of an investigation, the sole custodian of the original recovered information is the investigator and he/she is expected to arrange the downloading and read-out of the information, keeping the shipowner informed with a copy of the VDR information early enough within the investigation process, and in some cases the expertise of a specialist may be required. Furthermore, flag States and coastal States are required to develop applicable domestic legislation to govern further access to VDR information and any disclosure of the information should be in accordance with Section 10 of the Code for the Investigation of Marine Casualties and Incidents (MSC/Circ.1024 of 24 May 2002).

Though prescribed by IMO, the development of national legislation regarding the access and use of VDR information has seen timid strides in flag States. The implementation of VDR regulations and the access and use of the VDR information globally has remained unregulated due to the non-existence of applicable national regulations. The Australian regulation on the access and use of VDR information, which is known to be the strictest globally, will be reviewed in the subsequent sections.

# 7 THE CASE OF AUSTRALIA

This part of the report offers an overview of the Australian regulation on the use of VDR. Australia is considered among the very few countries that regulate the use of VDR aboard ships by ensuring the freedom of information regarding safety, while not infringing on seafarers' privacy and thereby protecting their basic human rights.

## 7.1 THE AUSTRALIAN REGULATION ON THE USE OF VDR INFORMATION

A review of the Australian regulation on the use of VDR information as summarized by Springall[29] offers insight into this Australian policy, which the author regards as being the most stringent in the world.

The access and use of VDR information in Australia is governed by the Transport Safety Investigation Act 2003 (TSIA) once the recording has been tagged as an On-Boarding Recording (OBR). Section 48 of the TSIA defines an OBR as "a recording that consists of sounds and/or images of persons in the control area of a transport vehicle, made in order to comply with a law in force in any country, and any part of the recording needs to have been made at the time of the occurrence of an immediately reportable matter involving the transport vehicle and where, either:

1) any part of the recording was made while the transport vehicle was on a constitutional journey, or was made incidentally to such a journey; or

2) the recording was made in order to comply with the law of the Commonwealth; or

3) at the time when the recording was made, the transport vehicle was owned or operated by a constitutional corporation or Commonwealth entity; or

4) the immediately reportable matter occurred when the transport vehicle was on a route ordinarily used by transport vehicles on constitutional journeys; or

5) the immediately reportable matter also involved another transport vehicle that was on a constitutional journey or was owned or operated by a constitutional corporation or Commonwealth entity."

Matters referred to as "immediately reportable" and which have become known as an OBR include: the death of or a serious injury to a person on board a ship or in contact with the ship or anything attached to the ship or anything that has become detached from the ship; the ship being lost, presumed lost or abandoned; the ship suffering serious damage, or the existence of reasonable grounds for believing that the ship has suffered serious damage; a fire (even if subsequently extinguished), smoke, fumes or an explosion on or in any part of the ship; the loss of a person from the ship; the ship being or nearly being stranded, disabled or involved in a collision; contact between the ship and another object, including a wharf or buoy, resulting in the other object being seriously damaged or destroyed; the ship suffering a significant loss of stability to the extent that the safety of the ship is, or could be seriously endangered; any other matter regarding the operation of the ship that a reasonable person would consider seriously endangers or if not corrected, would seriously endanger the safety of the ship, its occupants or any other person. Furthermore, according to the TSIA, a Constitutional journey is referred to as a journey by a ship undertaking international or national voyage and trade, within or between Commonwealth States.[30]

As soon as it has been established that a reportable matter has become an OBR, the use of recovered data is most often limited to safety investigations by an independent body in charge of civil aviation, maritime accidents and other transport safety incidents in Australia, known as the Australian Transport Safety Bureau (ATSB). The ATSB determines whether a matter is immediately reportable and should be treated as an OBR, and in the latter case a declaration is issued accordingly, permitting access to the recording.

In Australia, the VDR constitutes an invasion of privacy for the operating crew that most employees in other industries are not subject to. As such, access to the OBR information is most often restricted to safety investigations. Copying or disclosure of OBR information without authorization by the TSIA is considered an offence punishable by law with a penalty of up to two years of imprisonment. According to the TSIA, OBR information should not be used for civil legal proceedings unless the ATSB issues a certificate to the effect that the disclosure of the information is not likely to interfere with any investigation. The flag State of Australia has also placed other stringent restrictions applicable to the use of OBR information in criminal proceedings, disciplinary action, civil proceedings, coronial inquests and parliament and royal commissions.

Section 55 of the TSIA restricts OBR information from criminal proceedings against crew members. Only the police can be granted access to such information for the purpose of the investigation of the offence against the law of the Commonwealth, a State or Territory. According to Section 54 of the TSIA, OBR information cannot be used against employees for disciplinary actions. Moreover, OBR information is not authorized to be used for civil proceedings, except in the case where the ATSB ascertains, through the issuance of a certificate, that the disclosure of such information would not interfere with the investigation.

This occurs in extreme cases and under these circumstances such a certificate is most likely not to be issued. If, however, the need to issue the certificate is imminent, the court first conducts a public interest test in accordance with section 56(3) of the TSIA to ascertain that certain conditions are met to admit the OBR information as evidence. The court ensures that: 1) the material question of fact in the proceedings will not be able to be properly determined from the evidence available to the court; 2) the OBR information, or part of it, if admitted in evidence in the proceedings, will assist in the proper determination of that material question of fact; 3) any adverse domestic and international impact that the disclosure of the information might have on any current or future investigations is outweighed by the public interest in the administration of justice.

Moreover, even if the court acknowledges that the OBR information can be used as evidence after ascertaining the above, Section 58 of the TSIA prohibits such information from being used to determine liability in cases brought against a crew member. Additionally, the court also has the authority to restrict the kind of information to be made public or communicated and furthermore by whom. In coronial inquests circumstances, the ATSB is only allowed to provide the OBR information to the coroner at his or her request provided it has been established that access to the information is unlikely to interfere with related investigation. On accessing and examining the OBR information from a camera, the coroner may determine if access to all or part of the information should be unrestricted. The coroner also has the authority to place restrictions on which part of the information should be published and to whom. Lastly, the parliament and royal commission have full access to OBR information; the restrictions do not extend to them.[31]

In summary, it is observed that the Australian policy on the use of VDR data is remarkably more stringent and proscriptive compared to the IMO guidelines on VDR ownership and recovery as well as the MCI Code. The basis for the Australian Government's restrictive policy on VDR information access and use is to ensure the freedom of information regarding safety without restraint due to fear of incrimination. This policy also supports the functional independence, autonomy and objectivity of the investigative body to motivate the transport industry stakeholders to have confidence in the recommendations ensuing from such investigations and to accept and willingly implement them. It is the opinion of the policy developers that injudicious use of the OBR information is a prejudice to transport safety, which is a substantial basis for its restriction.[32] It therefore follows that other flag States could copy from the Australian "best practice" to prevent the invasion of seafarers' privacy and protect their rights.

(Photo credit: Jaemin Heo)

# 8 OTHER REFERENCE CASES FROM THE USA AND DENMARK

**INFORMATION RECORDED IN A VDR CAN BE RETRIEVED LONG AFTER IT IS RECORDED AND USED DURING INVESTIGATIONS FOLLOWING AN ACCIDENT OR INCIDENT. DATA CAN BE RETRIEVED, ANALYSED AND, IN SOME CASES, MAY END UP IN A COURT OF LAW WHERE A CREW MEMBER IS EITHER ACCUSED OR CONVICTED OF AN ILLEGAL ACT. (CEO OF DANELEC).**

As part of this research study, an interview was carried out with the Chief Executive Officer of Danelec Mr. Casper Jensen, a company that manufactures VDR equipment and based in Denmark. The CEO confirmed that information recorded on a VDR can be retrieved long after being recorded and used during investigations following an accident or incident. Data can be retrieved, analysed and, in some cases, may end up in a court case where a crew member is either accused or convicted of an illegal act. Additionally, while IMO timidly regulates VDR information access and use, most countries in the European Union (EU) implement the EU Marine Equipment Directive (2014/90/EU).

The lack of national regulation relating to labour rights in this domain is evident. The CEO confirmed that only data from discussions among crew members at the bridge may be recorded. All other data collected is in the form of digital or analogue input from sensors, which do not relay any personal information about crew members or other sensitive information about the crew. Crew members are usually informed about the recordings made on the bridge.

Danelec provides easier access to VDR information in the event of a distress or incident by storing the data in a Cloud Storage (CS) solution. Only the central data and not the day-to-day communications among crew members are stored in the Cloud. The issue of regulation governing labour rights is a common global concern. Even in the USA where strict regulation has been adopted governing access to cockpit voice data following aviation incidents, no such stringent regulation applies to the maritime industry.

Furthermore, work experience shared during an interview with a former engineer from Delta Airlines and a current accident investigator at the American National Transportation Safety Board, Mr. Michael Portman, on the recording, access and use of data from Flight Data Recorders (FDR) also highlighted a secondary flight recording system, called a Quick Access Recorder (QAR).

A FDR is "a required device that records pertinent parameters and technical information about a flight. At a minimum, it records those parameters required by the governing regulatory agency, but may also record a much higher number of parameters. An FDR is designed to withstand the forces of a crash so that information recorded by it may be used to reconstruct the circumstances leading up to the accident." (United States Department of Transportation/Federal Aviation Administration, 2004).

Mounted on a FDR unit, there is usually a second recorder, known as a Quick Access Recorder (QAR), which is a recorder designed to provide quick and easy access to raw flight data. Data recovery from an FDR, just as from a VDR, is labour intensive, so a QAR offers easier access for crew to quickly download the data. Rather than having to download content from the FDR "black box," the QAR enables the insertion of a pen drive to easily download the data at the press of a button. The data includes the flight's location at any given time. The raw data is subsequently transmitted to a data warehouse for an engineering team to process. The raw data mainly consists of flight parametric data. However, the engineering team can also access data that identifies certain incidents where there has been a reduced margin of safety, such as when conducting a hard landing. The data is later processed by an IT company that manages a server farm contracted by Delta. All data is funnelled to them and is processed securely.

The interviewed engineer furthermore reported that the aviation industry no longer blames the pilot when an accident occurs. It is gradually being acknowledged in the industry that environmental factors may lead to a pilot making a mistake.

This perception has also been adopted by the pilot union Air Line Pilots Associations, International. In fact, when a flight gets flagged, a gatekeeper is alerted, who is a Union representative. "A gatekeeper is a pilot who has worked for the airline, is also a member of the Union, and has this additional position through the Union. So technically, they're working for the Union." The gatekeeper also receives a copy of the full raw data. Questions on how to identify the pilot of the flight rarely emerge. However, other information may help the investigator identify the operator. Such as information on flight number, date of the incident and the route of the aircraft. This information can be provided by studying the scheduling system, which may provide clues on who the operator was. Indeed, gatekeepers have access to this kind of information. Usually, two to four Delta employees also have access to the data. However, these company representatives are not involved in any punitive action. They do not have the authority to punish pilots but simply to help process the data.

The interviewed engineer emphasized the importance of extracting data from multiple different sources to shed light on an incident, because if an analysis is based on data from one angle only, conclusions may be skewed. That is why it is important that gatekeepers after receiving the information undertake a number of actions:

"They will work with the engineers to know if the pilot filed an Aviation Safety Action Program (ASAP) (i.e. self-report) to report something strange that happened or which he observed. Or if not, they would reach out to the pilot to ask for an explanation about what happened. And there's a whole big umbrella project called a non-punitive safety culture designed for such situations. It is designed to basically allow pilots and operators to come forward voluntarily and report if they made a mistake and that it wasn't intentional. If they come forward and report that honestly, then the Federal Aviation Administration (FAA), the regulator and the airline have agreed that they will not take disciplinary action. However, there are a couple of exceptions to this. Things like wilful negligence, severe violation of rules, showing up to work absolutely plastered drunk, then they're not protected. But if you were supposed to run a particular checklist and just forgot, and as a result of that something happened, then you're protected. So, because the FAA, the regulator, and the operator all agree, I would rather know about it, and not enforce it, than not know about it, and then all of a sudden, you have a smoking hole in the ground. And so, the approach they adopted is that they have these big meetings where they look at the data that has been scrubbed. They look at the reporting and basically deliberate on what can be done to prevent such a situation from occurring again. In such situations, they may doubt whether to engage the pilot or operator involved again. However, due to the data having been scrubbed, neither the operator nor the date of the incident can be identified. They just know some very vague information about the situation. In such instances, they may be able to offer suggestions on what to do with the pilot. They may decide to train the pilot a little bit more on a particular aspect that seems to be missing, or remind the pilot of a particular chapter of the operations manual. In short, the investigators come out with some sort of a fix to the situation. If the same thing happens with different pilots within intervals of a month or two so that a trend is identified, then it may be inferred that the issue may be an inadequacy in the company's training, or that something has not been done correctly."

In summary, this section demonstrates that pilots' rights are well-protected and encourages them to be upfront. With the voluntary reports they submit, only the gatekeepers gain access to detailed information, such as what date and time the incident occurred, what the route and flight number is, etc.…. When they study the data and compile their report for operators and regulators, they scrub the data, removing all details regarding identification and leaving only the flight number and an account of events. The gatekeepers are given feedback from the committee and may approach the pilot concerned to report on the committee's decision, which is totally non-punitive. Any sanction may be to the extent of requiring particular training.

These efforts to protect pilot's rights are a mandatory measure governed by the United States Code of Federal Regulations, 14 CFR § 13.401 - Flight Operational Quality Assurance Program: Prohibition against use of data for enforcement purposes. The code requires all airlines to operate a voluntary Flight Operational Quality Assurance (FOQA) programme that is acceptable to the FAA. The FOQA programme is "an FAA-approved programme for the routine collection and analysis of digital flight data gathered during aircraft operations, including data currently collected pursuant to existing regulatory provisions, when such data is included in an approved FOQA programme". Unfortunately, no such legal requirement is present in the maritime industry.

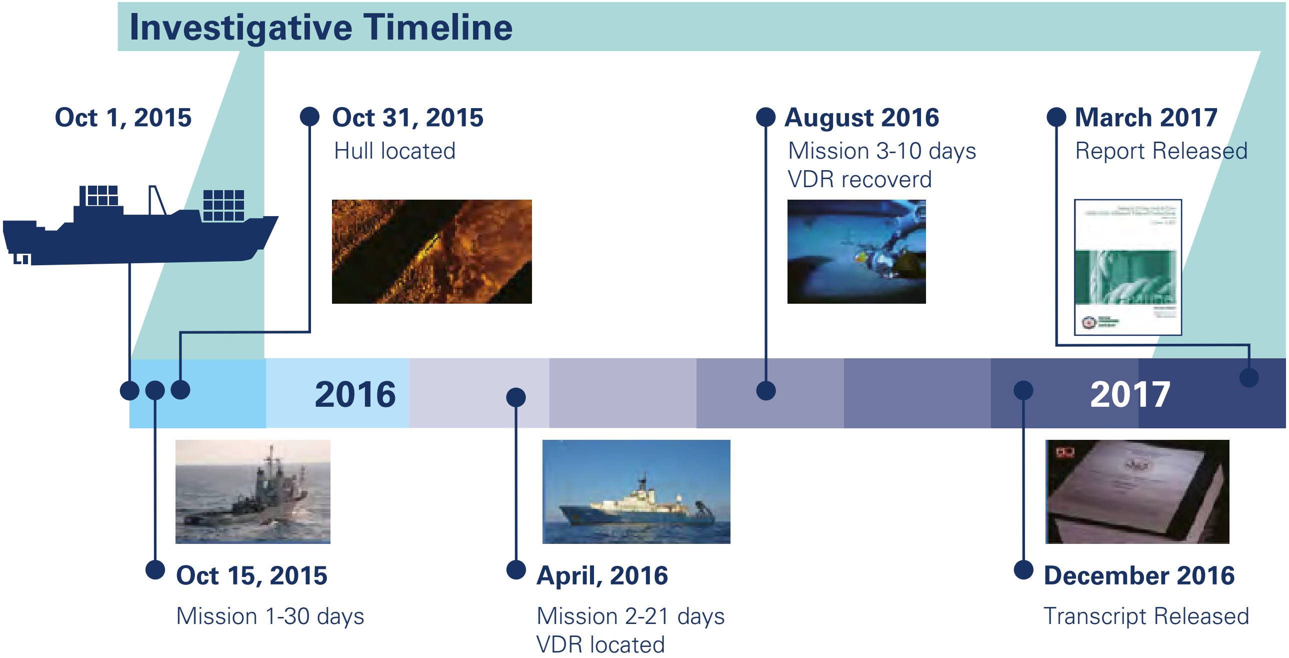
An interview was furthermore carried out with Mr. Sean Payne, the principal investigator for the case of a US-flagged ship named El Faro, which sank off the coast of the Bahamas in 2015. The investigator handled the VDR data recovery for this case. Our interviewee discovered that although the installation of VDR on board ships is mandatory according to the IMO, VDR equipment is generally not very well maintained. Moreover, no one studies the data unless there has been an incident. In comparison, the investigator attempted to copy from experiences in the aviation industry on how flight recorder data is used to optimize flight operations by monitoring the engine parameters to understand engine operations, such as overheating and low oil pressure. Such information would help shipowners make informed decisions on what to change in their operations so the engine would not be damaged or to alter fuel routes to minimize fuel consumption.

The same approach to utilising flight recorder data could be applied to maritime operations to ensure safety improvements, quality assurance as well as cost-savings. Naturally, there is a risk that crew data could be abused by employers.

However, according to our interviewee, this should not be the point of focus with VDR data because such converzations lead to the questioning of labour rights, crew privacy and job security. However, within aviation there are laws that protect crew from the use of their FDR data, which renders data on individual crew members uninteresting to employers. Such laws are not applicable in the maritime industry.

It was noted from this interview that large airline operators have adopted a workplace safety and crew protection culture where individual crew members are not identified during investigations of incidents or accidents. Nevertheless, small airlines know exactly which crew members were involved and therefore tend to punish them. Therefore, general regulations that protect crew rights are just as important a topic in the aviation industry as is the case in the maritime industry.

FIGURE 5.1.5 SS El Faro investigation process




Source: Sean Payne[33]

# 9 CONCLUSION

Artificial Intelligence (AI), big data and algorithms are today at the heart of debates on social transformation. In the maritime industry, the application of AI technology and the data linked to its use is still in its infancy. The horizon seems distant, but the prospects of technological change are already setting the players in motion – among innovators, established professionals, customers, and users – which affects the dynamics of workplace transformation. AI has made spectacular progress in recent years. Research-based technologies, such as machine learning and deep learning, have emerged from labs to perform tasks previously inaccessible to machines, such as recognising an image or a voice.

AI mainly promises to perform complicated yet repetitive or highly regular tasks. But even such a limited application risks undermining employee autonomy, subjecting them to increasingly insidious automated control and associated psychosocial risks.

AI is still in its early days in the maritime industry, which is why no specific examples of its application are so far available. In this study, we have therefore turned to VDR technology as a source of data and studied how this data may potentially be exploited by shipowners without specific regulation protecting the rights of workers.

Improving working conditions remains an important challenge at workplaces due to new AI technology increasingly becoming a risk factor in relation to alienation and work intensification. Progress in working conditions depends on how the productivity gains enabled by AI are distributed or how choices are made when organising tasks and teams.

The maritime industry must prepare for the widespread use of AI. This technology opens new perspectives for workers, organizations, and structures, yet also poses risks of deteriorating working conditions, which should not be underestimated. Risks include loss of autonomy, intensification of work, surveillance, etc.

Based on the analysis presented, the report identifies four areas within which responses are required in relation to the challenges raised by AI and big data on board ships:

1. Ensure that seafarers retain ownership and control over the data generated about them while serving on board ships;

2. Data generated about seafarers on board should be used for the sole purposes of security and safety;

3. International legislation should be passed governing the onboard use of AI and big data that enshrines the principle of responsibility for the impacts of their use;

4. Ensure the training of workers in the challenges of tomorrow. Seafarers should be made aware of the technical, legal, economic and ethical issues posed by the use of AI tools.

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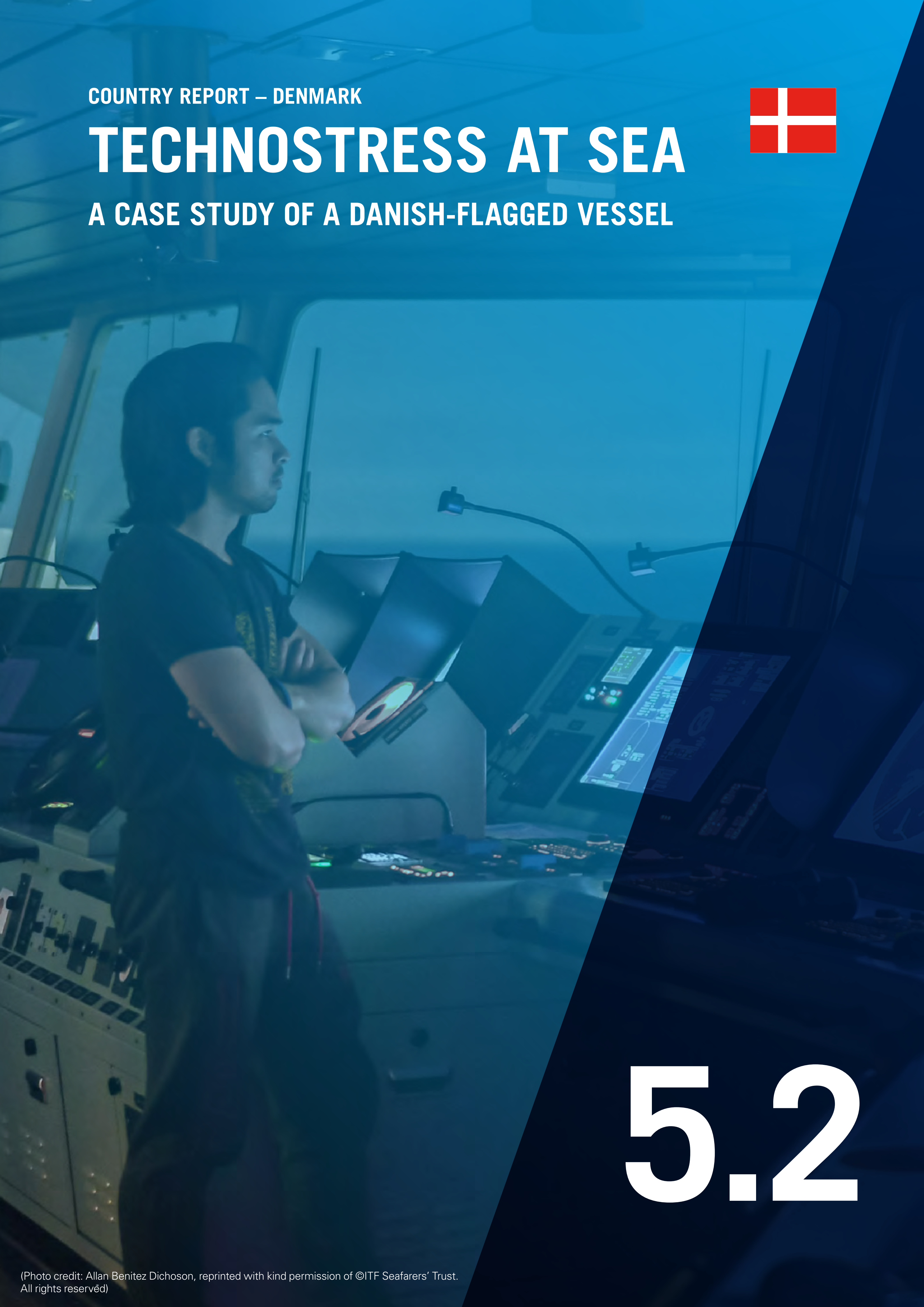
COUNTRY REPORT – DENMARK

# TECHNOSTRESS AT SEA

## A CASE STUDY OF A DANISH-FLAGGED VESSEL



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# 1 EXECUTIVE SUMMARY

Technological development has been an inevitable part of humankind since industrialization, and new technologies are continuously being developed, stimulating excitement and anxiety in potential users. More societal pressures around technologies, such as Information and Communication Technologies (ICT), have increased, leading to psychosocial work stress.[1]

The focus on studying stress in the world of work has increased since the 1990s, particularly on the impact of work-related stress on workers' health and the management of labour affairs. There is greater awareness among researchers and policymakers of the effects of psychosocial hazards and risks as well as work-related stress. Occupational Safety and Health (OSH) has expanded beyond its traditional scope to incorporate behavioural medicine, occupational health psychology, and social wellbeing.[2]

Working on a ship is becoming more and more stressful due to higher expectations regarding performance and greater emphasis on the achievement of competitive advantage, leading to long working hours and fatigue. Additionally, with the pace that technology is being integrated into shipping, seafarers are increasingly experiencing pressure to rapidly acquire new skills and competences, leading to serious consequences for their mental health and wellbeing. In counter response, the Just Transition discourse places emphasis on seafarer's health and wellbeing, noting the important role they play at the centre of the shipping value chain and the need for them to be in the right state of mind while exercising their duties. In this context, the ship's bridge and the Engine and Control Rooms (ECR) are of central importance to the overall vessel operation and have become increasingly technologically sophisticated and computerised.[3] Technological progress imposes pressure on seafarers, who are at the forefront of maritime operations. Seafarers need to keep up with the fast-growing pace in the development of new technologies, which is known to cause work-related stress, a concept known as technostress.

This country report explores technostress in the maritime sector and its extent, assessing the possible adverse effects on seafarers at the bridge, and in the ECR, focusing on the Danish flag State. The report aims to elucidate the linkage between technology and work-related stress among seafarers and raise awareness of the magnitude of the issue in the current context of the world of seafaring. To this end, the report provides an overview of the prevalence and impact of technology-related stress at the bridge and in the ECRs. It examines legislation, policy and interventions for its management. Field visits and semi-structured interviews were the methods used in achieving this goal.

As a result of this report, the following recommendations have been made within four areas: regulation, awareness, training, and discussions with social partners:

| | |
|---|---|
| 1 | **Regulation:** It was observed that despite the existence of international and regional regulations regarding stress in the workplace there is an absence of regulation regarding technostress internationally, regionally, nationally and even within the industries. In Denmark, maritime regulation regarding technostress is non-existent. It is nevertheless important to recognise this stress factor and its psychosocial impacts on workers, especially seafarers. |
| 2 | **Awareness:** Although technostress has proven to affect the mental health of seafarers, those affected seem unaware of the gravity of the issue. Raising awareness in the maritime community requires disseminating research results through various means, such as at conferences, seminars and expert meetings. |
| 3 | **Training:** For new technologies to be correctly operated, seafarers must be adequately trained before joining new ships. Training enables the users of these technologies to be confident during routine operations, thereby preventing techno-anxiety. Seafarers should be granted time and financial support to undergo training. In addition, maritime schools should update their curricula to align with modern technologies. |
| 4 | **Discussions with social partners:** the involvement of social partners in the entire process of the adoption of new technologies is essential. It allows seafarers to express their feelings regarding the issues they face with the new technologies they are often unprepared for. |

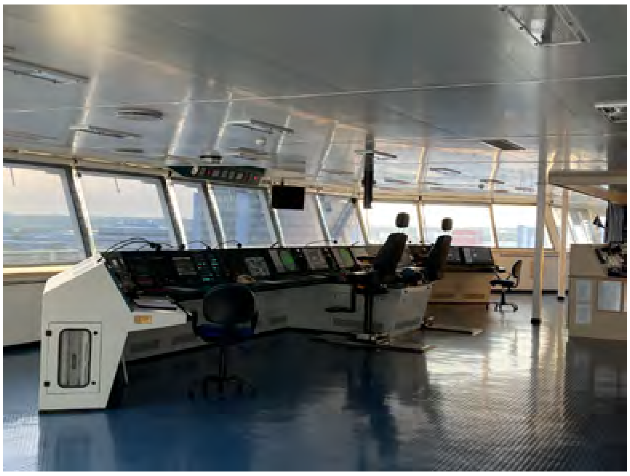
# 2 INTRODUCTION

The shipping industry has evolved since the nineteenth century with new technologies that aim to modernise operations and render them more user-friendly, safer and profitable for seafarers, shipowners, the economy and the environment. New technologies, such as Artificial Intelligence (AI), Big Data Analysis (BDA), the Internet of Things (IoT), digital route management of ships, smart propulsion systems, smart manoeuvring control / autonomous control, smart defence technology, blockchain technology, robotics, drones, 3D printing and Augmented Reality (AR),[4,5] are some of the technologies that have transformed, or have the potential to transform, the shipping industry from the traditional hybrid human-and-machine-driven industry to a solely machine-driven industry.

The application of these new technologies in shipping[6] shows that AI, among other uses, has the capability to classify and differentiate containers and goods based on their time frame of delivery. This ensures that goods with an urgent requirement are prioritised over others and are thus loaded onto the container vessels that reach the destination at the earliest, thus smoothening the flow of commerce and commodities between ports. In an industry driven by data like shipping, arranging data in a constructive manner can be challenging. BDA collects, sorts, arranges and attempts to correlate the masses of information, such as container types, weights and destinations, or data about ship characteristics, such as trim, stability, engine performance and communication, and draws inferences from large amounts of raw data to make useful conclusions.[7] Moreover, IoT application on vessels provides the ability for users to control and operate objects using either their phones or a configured remote control. This implies that electrical systems, for example, could be turned off and on by a single click from a remote device. Within shipping, the opportunities for such applications are obvious. Remote control can facilitate operations that would otherwise have required physical presence by crew members or passengers. Navy supply vessels benefit from the same advantages. Here, smart technologies can accurately route, deploy and control the vessel, allowing the logistics division to operate more efficiently. Furthermore, innovative technologies, such as blockchain technology, offer the potential to transform shipping. Applied appropriately, it is seen to benefit the provision of high data quality and to support configurable smart contracts, etc. Moreover, robots are used for maintenance, security and the inspection of vessels. Some shipping companies are replacing people with robots on their vessels for the performance of high-risk duties, such as hull cleaning. Drones are also being commissioned to deliver goods to vessels and for security, surveillance and remote inspection. 3D printing is being used to resolve the issue of timely delivery of spare parts on ships. AR visualization is used with the inspection of vessels and the execution of repairs and maintenance, which all takes place without the physical presence of a technician. Ship design and building companies also use AR to simulate virtual models, which can help resolve many issues early in the design process.[8]

More specifically, a ship's bridge has evolved over centuries from being a traditional wheelhouse, i.e. a deck space with a barrier but no roof or walls, to becoming a covered space with chart room and roof.[9] Likewise, the navigational technology at the bridge has evolved from astronavigation to the use of radio devices, such as Radio Direction Finder-RDF, Decca, Omega, and Loran.[10] Monitoring vessel position paths for collision avoidance was originally enabled by binoculars. Later, the radar was invented, which over the years has developed into a more sophisticated technology. More complex technology is currently being developed for the

FIGURE 5.2.1 Bridge, M/F Flandria Seaways of Copenhagen



Source: Photo taken by the principal author, Khanssa Lagdami

FIGURE 5.2.2 Bridge, M/F Flandria Seaways of Copenhagen

Source: Photo taken by the principal author, Khanssa Lagdami bridge, which is also seeing upgrades to existing systems. This evolution in bridge design and its applied technology has over the years considerably changed the bridge as a working space.[11] Bridge system manufacturers now combine devices, such as GPS, AIS, ECDIS, ARPA, Speed log, Gyro Compass and Echo Sounder, in a unified console called the Integrated Bridge System,[12] which is defined by IMO as "A combination of systems which are interconnected in order to allow centralised access to sensor information or command/control from workstations, with the aim of increasing safe and efficient ship management by suitably qualified personnel".[13]

A ship's ECR is of fundamental importance to the engine department and the overall operation of the ship. With digitalization, newly built ships have become sophisticated computerised entities, especially the ECR where the engine department crew increasingly works with remotely controlled systems.[14] A study by Gundogdu and Josefsson[15] identified several changes in work performance on board ships enabled by digitalization that offers benefits in the form of reduced workloads and a shift from high-intensity work to monitoring and administrative tasks. The engine room has also seen a reduction in human intervention due to computerization and automation, which has enabled manually operated equipment, including pumps, gauges and analogue switches, to become remotely operated by computers located within the ECR. The study found that engineers, on one hand, are satisfied with the current level of digitalization at their workplace since it ensures a reduction of high-intensity work and therefore offers greater comfort. Digitalization has also enhanced job efficiency due to the interconnectedness of all systems on board. However, the engineers also expressed dissatisfaction with the level of stress and change in their lives and work environment brought about by the digitalization of ECR operations. Another study, which saw the participation of 731 engine officers in the Swedish merchant fleet, reported that a substantial amount of workspace-related stress is observed among engine officers. The study concluded that their stress is caused by the fast pace of technological development, organizational changes and corporate demand for greater economic performance.[16]

FIGURE 5.2.3 Engine Control Room, M/F Flandria Seaways of Copenhagen

Source: Photo taken by the principal author, Khanssa Lagdami

## 2.2 IMPACT ON SEAFARER'S HEALTH AND WELLBEING

Technology is changing the shipping industry workforce with jobs disappearing at a fast rate. Robots are becoming mobile, smart and collaborative, and intelligent machines are taking over a wide variety of both manual and cognitive tasks previously executed by humans[17]. Additionally, workers are increasingly being supervised by monitoring technologies and algorithms to the extent where humans could in the future face becoming managed by intelligent machines. The globally interconnected economy and other issues, such as the COVID-19 pandemic, have enhanced the need for a more flexible task organization, which has resulted in new ways of working, including using virtual platforms. It therefore follows that digital technologies and new duties in their operations present challenges for OSH regulations[18]. Seafarers are vital to managing a ship's machinery and operations, yet their work, sleep and leisure time is confined to the same space. The nature of their profession exposes them to immense challenges for months. Watch-keeping officers at the bridge are obliged to observe strict navigation to avoid collisions and other incidents, while the engineers work tirelessly to operate, monitor, troubleshoot and maintain various ship systems.[19]

Engineers in the ECR are often exposed to OSH challenges due to the enclosed nature of their workspace, which is characterised by a torrent of loud noise, vibrating equipment and the emission of toxic and hazardous substances from engine oils. All these challenges lead to psychosocial and organizational hazards for workers. ILO[20] defines psychosocial hazards as "interactions between and among work environment, job content, organizational conditions and workers' capacities, needs, culture, and personal extra-job considerations that may, through perception and experience, influence health, work performance and job satisfaction."

As a result, psychosocial and organizational risk factors deserve particular attention due to the high level of work-related stress and poor mental health they entail[21]. Naturally, the fast-evolving pace of technological change and development are welcomed by the shipping industry.[22] However, the stress that accompanies the use of technologies risks negatively affecting the mental health of the seafarers faced with the challenge of routinely working with them.[23] The medical term for this kind of stress is technostress.[24]

# 3 LITERATURE REVIEW

Technostress has not been sufficiently studied in the maritime sector. By definition of the term, technostress applies to technology-driven workplaces. Technostress as a term was originally coined in the 1980s by Brod,[25] who defined technostress as a situation of overall stress experienced by an individual due to inability to adapt to new technology in a healthy manner.[26] Within the world of IT, technostress is regarded as the dark side of technology and has been defined as the psychological state of stress associated with IT use[27] governed by a number of stress factors, or stressors.[28] According to Salanova et al.,[29] the evident multidimensionality of technostress is defined as "a negative psychological state associated with the use or the 'threat' to use new technologies," which leads to "anxiety, mental fatigue, scepticism, and a sense of ineffectiveness".[30] According to Cazan et al.,[31] workers in the ICT field exhibit high levels of computer anxiety, experiencing feelings of discomfort, frustration and stress. When using computers and accessing the Internet, they anticipate catastrophic consequences of errors. The stress factors that individuals experience fall into several categories known as "technostress-stressors"[32] as described by Tarafdar et al.[33] These stressors include techno-invasion, techno-overload, techno-complexity, techno-insecurity, and techno-uncertainty. Other stressors include role ambiguity, work overload, job insecurity, work-home conflict, invasion of privacy, interruptions and over or under acquisition of information.[34] Workers may not be able to handle the flood of information accompanying new technologies, leading to techno-overload. The results obtained by Stana[35] demonstrate that ICT itself is not the sole cause of technostress. Other techno-stressors include the flow of information and the feeling of constantly being reachable and connected via technology, resulting in a sense of intrusion of personal time and space. Additionally, workers may have to invest time and resources in learning how to master the complexity of the technology and engage with steep learning curves, causing techno-complexity. The fear or threat of losing their job due to other individuals being better at understanding the technology leads to a sense of cynicism towards technology, which is a stressor known as techno-insecurity. Moreover, constant changes and upgrades to technology lead to feelings among workers of frustration and anxiety, a condition known as techno-uncertainty. Techno-anxiety relates to the use of computers or ICT appliances and generates fear, apprehension and agitation in the user. This includes feelings of uncertainty when a person is required to carry out an action using ICT (e.g., pressing a button) and to a related fear of loss of information.[36] All these factors are techno-stressors, which combined contribute to the magnitude of the impact that technostress leverages on the occupational health and safety of workers, known as techno-strains. These are defined as an individual's psychological, physical and behavioural response to stressors[37] has aggregated examples of techno-strains from the literature and reports that demotivation, lack of creativity, disruptive behaviour, concentration issues, social relations issues, anxiety, fatigue, workaholism and addiction are the most prominent such techno-strains.

In the shipping industry, a study by Gundogdu and Josefsson[38] reported some of these technostress stressors being experienced by engineers working in the ECR. Techno-overload was observed when alarm functions on monitors were activated in response to large amounts of machinery data flooding the system. This data is expected to be interpreted as fast as possible to address system breakdowns and prevent further failure. Such monitoring systems often provide excessive, incomprehensive information, sometimes unrelated to the failure observed, making it difficult for seafarers to process this overload of information within a short period of time and making it even harder to find the source of system failure. Moreover, the lack of time available to analyse the data and the stress of not knowing the problem and being unable to identify its causes results in fear, panic and agitation, a situation known as techno-anxiety,[39] which may lead to accidents.

The same study reported how engineers would face a complexity of different interfaces being used on different monitoring systems due to various manufacturers each applying their own different approach to interface design, a fact the engineers perceived as being complex and user-unfriendly. Excessive use of abbreviations, misspelling and complex menu items caused stress with the engineers, who could barely access the required information. That engineers need to invest time and effort in learning the meaning of technical abbreviations and in familiarising themselves with different interface designs are signs of techno-complexity.[40]

Techno-complexity was also observed in ECRs where the machinery is controlled by software-based computerised systems and where push buttons are used to start and operate the systems. Smart systems execute nonstop commands, in sequence, without a need for any further intervention by the engineers. Subsequently, in the event of a sensor failure, faulty software or related issues, the automated system experiences a crash due to its dependency on software and the sequence of sensor information. The inability to switch between the automated systems and manual operation is an aspect of techno-complexity that may lead to disaster.

Furthermore, the complexity of ships with digitalised ER and ECRs also poses challenges related to ergonomics. Engineers reported that the quest to render ECR operations more efficient has raised challenges related to un-ergonomically designed monitors, which are generally too small to view and overly sensitive to wet or dirty fingers, making it very complicated for engineers to execute their tasks. Also, finding, troubleshooting and fixing problems in the systems is usually very difficult due to the nature of the control software running in the background. All these issues lead to a feeling of frustration, scepticism and anxiety, causing techno-uncertainty among the engineers.

# 4 EXISTING LEGAL FRAMEWORK FOR WORK-RELATED STRESS AND MENTAL HEALTH

## 4.1 INTERNATIONAL LABOUR STANDARDS

The International Labour Organization (ILO) has adopted three main standards that uphold core values addressing psychosocial risks and the protection of workers' mental health, articulated in three main principles; namely, the requirement for work to be carried out in a safe and healthy working environment; the need for working conditions to consider workers' wellbeing and human dignity, and the real opportunities for personal achievement, self-fulfilment and service to society. Accordingly, the ILO Convention on Occupational Safety and Health, 1981 (No.155) and its accompanying Recommendation (No.164) was designed to protect the physical and mental health as well as the wellbeing of workers. It requires States to adopt, implement and review a systematic national policy on OSH accompanied by strategies for its application both at the national and workplace levels. This is envisaged to prevent accidents at work, and illnesses resulting from, linked with or occurring during working hours. This framework is also required to consider the relationships between the material elements of work and the workers or supervisors, and to adapt machinery, equipment, working hours and the organization of work and work processes to both the physical and mental capacities of the workers. Moreover, the definition of the role of occupational health services is inscribed in the Occupational Health Services Convention, 1985 (No. 161) and its accompanying Recommendation (No. 171). This policy portrays OSH as a multidisciplinary service with preventive and advisory roles that assist employers, workers and their representatives in developing and maintaining a safe and healthy working environment. This includes adapting work to the competences of workers to ease optimal work-related physical and mental health.

Finally, the Promotional Framework for Occupational Safety and Health Convention, 2006 (No. 187) and its accompanying Recommendation (No. 197) serve as a supplement to the other two main core standards. It provides the requirements for and defines the functions of a national structure and its relevant institutions and stakeholders responsible for implementing a national and enterprise-level policy for safe and healthy working environments as well as the steps to be taken to build and maintain a preventive safety and health culture at a national level.[41]

Furthermore, the ILO guidelines for implementing occupational health and safety[42] (2014) highlights an array of detrimental effects on mental health resulting from the conditions of the seafaring profession. Stress, anxiety, depression, post-traumatic stress disorder (PTSD) and suicide may rapidly adversely impact the work performance, safety behaviour and wellbeing of seafarers and subsequently affect their working ability as well as their life in general. Other factors at the workplace, such as physical confinement within their working environment, treatment received from colleagues, traumatic incidents or lack of job motivation, can also cause mental health issues. Apart from stress factors resulting from the workplace, mental distress may also be related to concerns about events at home.[43] MLC, 2006 requires a tripartite cooperation between the competent authorities and the shipowner and seafarer organizations to develop effective measures to mitigate the adverse effects of work-related stress factors on the mental health of seafarers.

## 4.2 THE IMO STANDARDS

Although the International Maritime Organization (IMO), which is the standard-setting body responsible for regulating international shipping, has not sufficiently regulated psychosocial issues, certain mandatory and non-mandatory regulatory requirements relating to engine room design and layout are in place. Mandatory requirements include Chapter II - 1 of the International Convention for Safety of Life at Sea (SOLAS) regarding Construction – structure, subdivision and stability, machinery and electrical installations, which addresses the design and construction of the engine department, including specifications for the ECR. It also sets out the technical specifications of equipment layout and installation within the engine room. Moreover, IMO has developed guidelines for Engine Room, Layout, Design and Arrangement,[44] which is non-mandatory and whose scope encompasses five areas used to describe the human-machine environment; namely, familiarity, occupational health, ergonomics, minimising risk through layout and design, and survivability. Section 6.2 on occupational health addresses the effect of the engine room environment on crew members' health and performance, especially in aspects regarding noise levels, ventilation, air-conditioning and temperature regulation, lighting and vibration. It holds that enhancing workplace comfort will result in fewer accidents caused by psychological and physiological stresses. It necessitates the provision of air-conditioning in enclosed control rooms to provide regular relief from high temperatures and to optimise the performance of electrical and electronic circuits in the engine room. It also recommends the provision of heating or cooling facilities to other areas of the engine room to ensure the regulation of temperature and prevent its effect on the performance of personnel working during watch-keeping, maintenance and repairs. Additionally, machinery mountings in engine rooms are to be designed in such a way as to minimise machinery vibration and its long-term effects on the engine room crew. It is noted that these IMO non-mandatory provisions cover areas primarily related to the engine room. However, with the evident advancement in technology and the increasing importance placed on remotely controlled equipment as well as the processing of big data within the ECR, there is the need to take further measures to optimise the operational work environment in the ECR.[45]

## 4.3 REGIONAL STANDARDS

In the European Union (EU), the Framework Directive on Safety and Health at Work (89/391/EEC) governs the implementation of OSH within member States. Even though the Directive does not refer explicitly to "work-related stress" or "psychosocial risks", it requires employers to ensure workers' health and safety in all aspects related to work. It also requires employers to adapt the work to the individual, especially with regards to the design of workplaces, the choice of work equipment and the choice of work and production methods; and to furthermore develop a coherent overall prevention policy that covers technology, the organization of work, working conditions, social relations and the influence of other factors related to the working environment.[46] Other individual Directives within the meaning of Article 16 (1) of Directive 89/391/EEC include Directive 89/654/EEC concerning the minimum safety and health requirement for the workplace (the 1st individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) and Directive 90/270/EEC on the minimum safety and health requirements for work with display screen equipment (5th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC).

## 4.4 DANISH LEGISLATION

**IN DENMARK, ONE IN FOUR EMPLOYEES EXPERIENCE HIGH LEVELS OF STRESS. DESPITE MUCH RESEARCH INTO TECHNOSTRESS, THE ISSUE IS STILL NOT PART OF THE DEBATE.**

In Denmark, employers are compelled, according to legal provisions,[47] to prevent or control psychosocial risks in the workplace. The Danish Working Environment Act No. 2062 of 16 November 2021 and the Danish Working Environment Authority's Executive Order No. 1406 of 26 September 2020 on psychosocial working environment[48] are relevant in this regard. Some of the relevant provisions of the Danish Working Environment Act are discussed in subsequent paragraphs[49].

The planning and organization of work, which is an aspect of the Executive Order No. 559 of 17 June 2004 on the Performance of Work,[50] requires employers to plan and organise all aspects related to work in such a way as to ensure safe and healthy working conditions, and in further consideration of the principles stated in Annex I of the Order. Employers are required to ensure that no designs, plans, detailed solutions or working methods, which may be dangerous to or otherwise impair health or safety in connection with the performance of work, are prescribed or assumed to be used. Additionally, it also requires that, in the short or long term, employers should ensure that the overall impact on the employee's working environment does not impair the health and safety of the employees.

Regarding work performance, the provisions require that health and safety should be ensured when carrying out all aspects related to work. This is ensured in regard to an individual assessment as well as an overall assessment of the physical, ergonomic and psychosocial conditions of the working environment which, in either the short or long term, may affect the physical or mental health of the employees. In special cases in which there are physical or mentally harmful or stressful effects in either the short or long term, the DWEA may demand that special occupational health and safety measures be carried out. Such measures may be special welfare measures and any other occupational health and safety measures necessary for the prevention of diseases, wearing-down, accidents, etc. (Section 7. – (2)). Still regarding the performance of work, the regulation furthermore provides that efforts shall be made to ensure; firstly, that monotonous work involving a risk of physical or mental impairment to health in the short or the long term is avoided or alleviated; secondly, that the work pace does not involve any hazard of physical or mental impairment to health in the short or the long term; and thirdly, that work in isolation, which may involve a risk of physical or mental impairment to health, is avoided or alleviated (Section 9). Moreover, with the performance of work, it is required that the employer must ensure that the task does not involve a risk of physical or mental impairment to health as a result of bullying, including sexual harassment. (Section 9a). Section 11. -(1) requires that work be organised in a way as to prevent inherent danger resulting from work situations in which an employee is the only person engaged in a working process and which may involve specific danger to the employee concerned.

Furthermore, there is also Executive Order No. 96 of 13 February 2001 issued by the Danish Ministry of Labour on the Conditions at Permanent Places of Work, which requires the place of work to be designed and fitted out to ensure safe and healthy working conditions, based on both an individual and a general assessment of the working environment conditions that may have short or long-term impact on the employees' physical or mental health (Section 6).

## 4.5 SOCIAL PARTNER AGREEMENT

ILO labour Inspection Convention 1947, No. 81, in its Art. 27 provides that apart from laws and regulations, collective agreements on which the law is conferred are also part of legal requirements. Collective agreements are defined by ILO as "all agreements in writing on working conditions and terms of employment concluded between, on the one hand, an employer, a group of employers or one or more employers' organizations, and, on the other hand, one or more representative workers' organizations or, in the absence of such organizations, the representatives of the workers duly elected and authorised by them in accordance with national laws and regulations" (ILO Collective Agreements Recommendation, 1951 (No. 91)). The importance of collective agreements can be judged by their ability to enhance the requirements of a state's laws while upholding the binding obligations entered into jointly by employers and workers in respect of the minimum standards set out in national legislation. Rather, such collective agreements seek to complement or may even be more stringent than national legislation, all for the benefit of workers.[51]

Regionally, the European Social Dialogue Framework, which plays a fundamental role in identifying the importance of psychosocial issues and work-related stress, has concluded a number of agreements covering important aspects, such as parental leave, part-time work and fixed-term contracts. Social partners have also concluded framework agreements on work-related stress as well as other psychosocial issues. The EU framework Agreement on work-related stress states that the factors causing work-related stress may be addressed through a risk assessment process, and the measures can either be collective, individual or both. Although employers are responsible for determining the appropriate measures to be implemented, workers or their representatives are also required to participate and collaborate in implementing the measures.[52]

At the national level, social partners in some countries, such as Luxembourg, the Netherlands, Finland, Sweden, Spain, Belgium, France and Germany, have also developed agreements that set a framework for negotiations on work-related stress and other forms of psychosocial risks, which align with the EU framework agreement. In Denmark, collective agreements in the public sector have been concluded, establishing the rights and obligations for the signatory parties and their members.[53]

## 4.6 PROFESSIONAL ASSOCIATIONS AND NETWORK CONTRIBUTIONS

In 2006, ILO discussed a range of measures contributed to by international, regional and national professional and non-governmental associations advocating for the management of work-related stress and workers' wellbeing. Also contributing were professional networks at the regional and national levels who actively work with psychosocial risks and promote workers' mental health and wellbeing through research. Their aim being to gain greater insight into the nature and impact of psychosocial risks and to design efficient strategies to address them. An example of an international non-governmental body in this regard is the International Commission on Occupational Health (ICOH), which promotes the development of scientific knowledge on OSH. Their committee on Work Organization and Psychosocial Factors (WOPS) was established in 1996 with the aim of promoting awareness, research and education, disseminating good practices and influencing policy development in the areas of work organization and psychosocial factors. In addition, the International Organization for Standardization (ISO) is recognised as the world's largest developer of voluntary international standards. In particular, the ISO 10075 series includes principles, requirements and instruments for the measurement of mental workload. The standards were designed for ergonomic experts (e.g. psychologists, occupational health specialists, and physiologists) to enhance their knowledge of the theory and practice of methods as well as the interpretation of results. Other relevant international professional associations that promote various aspects of work-related stress, such as ergonomics, or provides education on related policy development and implementation or disseminate knowledge through events and conferences, include the International Ergonomic Association (IEA); the International Institute of Risk and Safety Management (IIRSM); and the International Stress Management Association (ISMA).

Within the EU, the European Academy of Occupational Health Psychology (EA-OHP) promotes research and education on occupational health psychology throughout Europe by means of the organization of conferences every two years. In addition, there is the European Network Education and Training in Occupational Safety and Health (ENETOSH), which is a platform created to share knowledge and educate on OSH issues, one of which is stress and psychosocial risks. There is also the European Network for Mental Health Promotion (ENMHP), which provides information, tools and methods, training and a communications platform for individuals interested in the subject. Similar professional organizations exist in the Americas and Asian Pacific regions.[54]

# 5 IMPACT OF TECHNOSTRESS ON SEAFARERS AT THE BRIDGE AND IN THE ECR: THE CASE OF DFDS

## 5.1 METHODOLOGY

Technostress is a well-known topic and is discussed within various fields, especially in the ICT industry. However, this study presents one of few attempts to investigate the subject in the maritime industry. The reported findings represent the perceptions and experiences of crew members on technostress on board the Danish flagged ship, M/F Flandria Seaways of Copenhagen, a ro-ro cargo vessel owned by the company DFDS.

A survey was developed to collect data on board M/F Flandria Seaways while sailing. The survey was modelled based on previous studies on technostress that reflect two dimensions of technostress: the technostress creators, which refers to the stress created when using technology,[55,56] and technostress inhibitors, which refers to the available resources that facilitate reducing technostress caused by ICT.[57,58]

The technostress creators include techno-overload, techno-complexity, techno-invasion, techno-uncertainty. Technostress inhibitors include training, new skills acquisition and raising awareness.

The voyage took place between 19 and 22 July 2022. The vessel, M/F Flandria Seaways of Copenhagen, was on a roundtrip voyage between Gothenburg (Sweden) and Immingham (UK).

FIGURE 5.2.4 M/F Flandria Seaways of Copenhagen


Source: Photo taken by the principal author, Khanssa Lagdami

The programme of the field research was as follow:

| | |
|---|---|
| 1 | Embarkation in Gothenburg |
| 2 | Study the bridge/navigation environment on the voyage between Gothenburg and Immingham. (Length of voyage: roughly 34 hours). |
| 3 | Study the cargo operation environment at the port while docked in Immingham. (Length of stay: roughly 9 hours). |
| 4 | Study the engine/machinery environment on the voyage between Immingham and Gothenburg. (Length of voyage: roughly 34 hours) |
| 5 | Disembarkation in Gothenburg. |

In total, the length of the roundtrip was roughly 3 days.

## 5.2 PRESENTATION OF THE FINDINGS

This part of the report analyses the perceptions of the crew members regarding the creators and inhibitors of technostress. In addition, they were also asked if they were part of the decision making regarding technological changes on their ship.

### 5.1.1 COMMUNICATION/PARTICIPATION ON THE DECISION-MAKING PROCESS

The participation of workers in decision-making regarding the implementation of new technologies that pose OSH risks in general, and stress in particular, is an important aspect of the professional life of employees. The employees taking part in this study considered it necessary for technology developers in the maritime industry to discuss their plans for new technologies with seafarers prior to development. They believe that shipping companies should decide on the extent to which new technology should be implemented due to the many rules and standards that such technology needs to adhere to. One interviewee explained that new technologies currently in the pipeline may cause stress with the crew since they need to learn cumbersome operation procedures. “There’s a lot of technologies coming that could also be desired by the crew. So, they are looking forward to getting this new technology, but it could be hard and stressful to learn a new system,” he reported. The interviewee also explained that although the ship is new there are even more advanced technologies on other ships.

Moreover, technological development in the maritime sector requires the crew to receive ongoing training. The crew also complained about technologies that are old on the market, yet are introduced on the ship as if they were new, which is a further cause of stress among the crew. To prevent stress, they preferred management to introduce the newest technologies despite any initial extra costs involved in training the crew.

“Some of the technology may already be five or ten years old. And there’s already new technology on the market that was not purchased. This can give you stress because it’s new on this ship, but still old technology. So, it could be helpful to get the new kind. That will cost extra learning time in the beginning, but in the end, it will eliminate other kinds of stress. So, I think it’s a balance somehow.”

Some seafarers are unprepared for the arrival of new technologies, which they perceive as representing rapid change, although they tend to adapt and learn when the technology has arrived. In addition, some crew members expressed not experiencing any stress or other OSH issues at all. This reflects work culture of obedience among seafarers in the maritime field who refrain from expressing their opinion out of fear of losing their job. According to the Captain, crew members refrain from sharing mental health issues. Culturally, crew members from some nationalities are concerned that if they express their opinion, they will lose their job. The Captain explained that if he were to visit the cabins of his crew, he felt sure he would find anxiety medication despite crew members not being open about the workplace stress they face.

### 5.1.2 TECHNOSTRESS CREATORS

#### TECHNO-OVERLOAD

The introduction of new shipboard technologies may also add to the workload of the crew. Often the crew is unprepared to deal with technical issues related to software. They find troubleshooting easier on older ships and get overworked when dealing with new technologies where solving the deeper issues requires many procedures. An interviewee explained that their work contract is a fixed contract with a fixed salary. Even if they work extra hours due to technology issues they receive no additional compensation.

“Since we have no overtime here, we have a lot of work outside normal working hours.”

Another interviewee stated that procedures were easier in the past when they used to routinely check rooms to see if everything was working properly. Now, they must handle everything through several systems, which is sometimes challenging, especially while they are still familiarising themselves with these systems. He stated that stress can affect everyone and not only the person dealing with the technology. New crew members need to be trained by others, which creates a feeling of stress for everybody. There are always new crew members on board who are unaccustomed to technology, which is stressful. Interviewees also believed that the company has no desire to spend money on training the crew because once trained, they tend to leave. This places responsibility on other crew members who gain an additional workload. When asked why there was a staff shortage, the interviewee answered that the company is trying to fill the gap.

Some crew members prefer performing extra hours at night when they feel they will be less likely to be disturbed. Others undertake technical and administrative tasks.

"For me, I start doing a lot of this illustration work during night time, because nobody will disturb me."

This, in turn, causes lack of sleep and fatigue. An interviewee stated that technology is supposed to help them, but sometimes it adds more workload instead, especially when things go wrong. Another interviewee explained that he is obliged to respond to urgent emails and correspondences. He also recognised that colleagues at the bridge (officers) undertake a lot of administrative work.

"I have to reply to this guy. And then, yeah, and somebody else has something. Then you have to go and search."

He also raised the issue of how the invasion of technology needs management and requires him to train new colleagues and respond to their questions. This can be very stressful, especially if a system or something else breaks down. Sometimes the issues that arise cannot be handled within a short period of time. The crew then has to work for extended hours, even all night. Depending on the situation, sometimes seafarers in the ECR work overnight to fix technical problems.

"The importance of the roof, we have to fix it immediately. Or we can do it during working hours. We have to do it immediately. We can work all night. But if we can wait until tomorrow, then we wait until tomorrow to do so."

Newly recruited crew members who have never worked on a ship before will not notice any changes to their workload because they are on their maiden voyage.

"I've never known anything else but this. I don't know if it's more or less work."

A crew member who shares her duties with a colleague does not feel she experiences technology overload since she can count on her colleague. If she cannot fix an issue, her colleague will.

"Because we are two people for one job. If I don't make it then the other two will take over."

When asked if his workload had increased due to the complexity of technology, one crew member explained that this depends. It is not necessarily the complexity of the technology that matters. Sometimes the cause of greater workloads and stress are grave system errors. He also explained that in addition to their regular duties, the ship also has other systems that require monitoring three times daily, which only adds to their workload.

" We have more systems we need to check and more technology we need to go through every day."

Also, not only does the complexity add more workload, so does the technology itself since the crew has to constantly check all the systems. Generally, the more technology there is, the more work needs to be done.

"It's kind of the same on every ship, but the more technology, the more different things you need to check. We have the book laying over there. We'd go through the technology systems and write down different figures."

Another interviewee said that technology adds to the workload but that the crew has no choice but to adapt to it.

"So, if there's more advanced technology, you have to adapt to it." The use of some technologies may also be part of a crew member's duties even when not included in their job description. For instance, alarms constantly sound everywhere on the ship. The crew needs to be available around the clock to turn them off or check which system is faulty. The interviewee reported that whatever he is doing, he needs to stop and respond to alarm notifications. Another interviewee explained that alarm notifications are generated by different systems, not just one, which is very frustrating for everyone. The researcher observed how the crew at the bridge spent a lot of time turning alarms off. When asked if he needed to respond to emails and administrative matters in addition to his regular duties, one interviewee confirmed experiencing a lot of such work and explained that the first engineer has an even greater workload than the second engineer. Another interviewee said he now works more at the computer, which definitely gives him a greater workload.

"Yeah, there's been more things to fill out. Forms and yeah, there has been a little bit more sitting in the chair."

Additionally, there is usually no salary compenzation even when the workload becomes excessive. An interviewee explained that he is not paid for extra work. His salary is the same whatever his workload and that sometimes is annoying.

Also, an interviewee explained that they receive notifications from computer systems that give them additional tasks that are not really part of their job description.

"Also, we have a system on the computer telling us what to do with different kinds of jobs that we also need to be aware of."

When asked if they face any other issues than Internet bugs, the interviewee confirmed always experiencing issues with technology. He gave the example of how before embarking from Gothenburg, the ship had been cut off from the Internet so that many tasks had to be performed manually rather than using technology.

"We have some old troubles caused by other technology, and in Gothenburg, where we are on shore power sometimes, that technology is sometimes messing things up. Yeah, technology, there will always be something not working correctly the way it should."

Generally, new technology means that crew members need to deal with tasks they experience as more complex due to not having been informed or trained in the use of such technology. Also, the transfer to this ship had been challenging for the interviewee due to having to adapt his methods to quickly understand and learn how these new technologies run. Moreover, the company alternates between using different types of vessels, which can cause a lot of confusion and difficulties in learning how to deal with the technology on the various ships. Most often, this is challenging and there is no time to familiarise yourself with all the systems.

When asked how he managed to switch between operating different technologies, one crew member said it was a question of routine. Despite the initial difficulty, it all became routine despite not all crew members being granted enough time to familiarise themselves with new systems. An interviewee gave an example of a programme difficult to master where he is still learning something new every day. He explained that he deals with at least six different systems on a daily basis and mentioned a new system that the company had just installed on the ship that no one initially knew how to operate. A colleague who had learnt how to use it now instructs others. The interviewee explained that he initially had to focus on the basics and then learn the rest quickly. There was too much information, so he had to give priority to what he needed to learn first. Another interviewee explained that the work shifts change very often, which can cause stress since this means that crew members must familiarise themselves with different procedures and routines with different co-workers. The interviewee explained that he sometimes disembarks for a couple of months at the time. On his return, he often finds it difficult to remember all the details of the new systems, having to learn to operate them all over again, which makes his work stressful.

When asked if technology creates more workload, the interviewee confirmed. The researcher was shown how the system works and how following the completion of tasks, crew members still needed to write down what they had done with a pen in a book, which adds to their workload, considering that all what they write down is already registered in the system. They are also pressured by deadlines, which they need to meet to avoid a work backload.

"You have all these deadlines and you're so focused on doing the jobs before the deadlines because if you don't, the jobs will just add up."

Sometimes they must work extra hours just to complete the tasks scheduled for the day. The explanation they are given is that if they fail to execute the tasks, they will need to complete them the following day.

"Sometimes even if you are tired, you feel like these deadlines have made you work for like two hours more, even though you just want to go to bed. Because, otherwise, you will have to deal with even more tomorrow."

However, another interviewee explained that to maintain mental health and to balance his private/professional life, he stops working when he needs to without putting in extra hours. He usually leaves some tasks for the next day. The interviewee added that the first officer has a lot of administrative duties besides her normal tasks, which includes sending emails and procuring supplies. They highlighted an example of how a new colleague, who was so stressed over having to respond to every feedback from technology, had caused stress among the whole team. The Chief Officer had a conversation with this colleague and advised him to relax a little. The interviewee added that he would not be surprised if this new colleague refrained from returning after his two-week break due to the very stressful week he had experienced attempting to deal with the technologies.

Sometimes, crew members do not report stress. One interviewee said that the Captain should assume the responsibility of asking crew members if something is wrong. However, this is not the way things usually work. The Captain makes no inquiries and the crew also fails to report. A crew member said that everyone feels stressed and that it is up to the individual to handle the situation. He thinks it would be better if work was slower rather than everyone later feeling sorry for the consequences.

While some crew members feel that their stress is caused by technological development, another interviewee disagreed, which is not surprising given the fact that he is a cadet under training without workplace responsibility. The interviewee explained that as a cadet, he is on the ship to learn and does not personally experience a work overload. Another interviewee explained that even with the greater workload, he prefers working on this kind of ship rather than the old ones. Asked whether the crew feels comfortable with the technologies they are required to work with, an interviewee explained that on this ship they have no obligation to deal with technology if they are not comfortable with it. However, he also stated that he is sure that elsewhere else the crew would be forced to deal with technology, whether they are comfortable with it or not.

Despite the impact of new technologies on crew OSH, one interviewee still believes that new ships with new technology are a good thing because this is what the future is about.

### TECHNO-COMPLEXITY

New technologies can be very complex and this complexity causes stress with the crew members entrusted to operate them. One interviewee stated that the complexity of some systems requires more than one week of training to understand them. These systems not only involve a lot of screen keys, they also involve many individual functions related to a single big camshaft. Some crew members work with six to eight different systems on a daily basis. Some of these systems have alarms that alert them at night when they need to deal with everything on their own, which can be quite stressful. They also explained that troubleshooting has become a lot harder and can be more stressful during an overload of information. Everything is constantly being monitored and evaluated onscreen. Since the crew is still in the process of learning, new crew members inexperienced with such technology may feel stressed.

An interviewee explained how crew members returning from working on other ships had in the meanwhile forgotten how to operate the technology and needed to start afresh. However, younger crew members expressed being more adaptive. When asked if a complex situation with a lot of navigational traffic could make him feel stressed, he expressed having no issues with that and furthermore experienced no issues using the technologies he was trained to operate. Being of the younger generation, he is used to using computers. Another interviewee said it might definitely be very stressful for workers who have never previously been on this kind of ship. He and his colleagues very often talk about the issue. The crew members recommended that each time new technologies are introduced on board, there should be some level of prior training to avoid stress for everyone. One interviewee had experienced his start on the ship as initially being stressful, but said there were always co-workers familiar with the technology who could answer his many questions.

"Yeah, in the beginning, it is. But we have some very smart heads out there. And we help each other. But I still think we could use some training before we start."

Unlike younger crew members, a more mature interviewee explained that technology is, indeed, an issue for him and he is so far learning by doing. One crew member remarked that technology is supposed to help but instead sometimes adds more work, especially when things go wrong.

"It is supposed to help us and minimise the work but I'm not sure it does so because every time there is something that the technology has registered as wrong, then this needs to be taken care of." Additionally, most crew members reported having to deal with many technological systems at the same time, and although moving from using one technology to another takes time, they manage to do so.

Another interviewee explained that he still does not understand everything but keeps learning as new challenges are overcome. The interviewee expressed sometimes feeling stressed at the complexity of the technology of the engine board. Another interviewee explained that due to the development of technology, the crew constantly had to adapt. Crew members now have more complex tasks because of the new technology, mostly due to not having been trained in the use of the technology. It was also challenging for some crew members on the ship in question to adapt to the new technologies.

Some of the difficulties encountered by crew members were due to being stationed on different vessels with different types of technologies, which creates a lot of confusion and difficulties in learning how to deal with the technology. Most often, technology adds a level of complexity. Some crew members did not believe that the company expected them to operate all the technology/systems, while another interviewee added that he believes no one on board knows everything but that they can figure things out together.

"The first thing is to not expect us to understand it all... And if there's a system nobody knows, then we all get together and figure out how it works."

Moreover, some systems can be quite complex, especially with the alarms. The alarm signals can be so loud that they would wake the crew from their sleep feeling perplexed and confused. Often these are false alarms that you switch off, but they will have disturbed your sleep. One interviewee stated that the alarms were especially stressful. Other crew members unpreoccupied with the complexity of the technology since they complement each other with the knowhow they each have. What one person does not know, others would. This is particularly the case when crew members substitute each other for the first time and handle new duties. They can always seek help from co-workers, although these colleagues tend to get irritated if you ask them too often, since repeating the same instructions several times also causes stress with them.

"I would not be so worried about what I wouldn't know how to do. It's quite clear what jobs different people have to do. For example, if I have to substitute as first officer because somebody's on vacation or sick or whatever, and the crew and the Chief Officer knows it's going to be my first time as a substitute. He knows that I probably don't know how to update this chart or something like this and it's no problem for me to say, 'can you show me?' Yeah! He wouldn't mind at all showing you as he understands that it would be my first time. But if I ask three or four times it becomes irritating. But the first couple of times, always ask."

Sometimes new colleagues forget what they are taught and need to return several times for assistance, which is stressful for everyone.

"He told me that 'I think I forgot something' and then he went up and double checked."

The interviewee explained how stressed his new colleague was since he did not know where to begin. It was very difficult for him to understand everything in just one week.

"When I came down, he was sweating, yeah, and we didn't know what he was doing. It was a complete mess I had to fix everything when I arrived and this also stresses me out.

Some seafarers are unpreoccupied with the complexity of the technology since they think that everything is not solely their responsibility and that there is always someone around who can deal with different aspects of the system. They believe that the culture on this ship is good and say that co-workers help each other to avoid feeling stressed about the complexity of the technology. The crew members gave different reasons why some people cannot easily deal with the complexity of new technologies.

To some crew members, the level of comprehension comes down to age and generation. One interviewee explained that having graduated from school only last year, it was easier for him to deal with technology than it would probably be for someone who had started sailing on traditional ships 15 or 20 years ago. As a cadet who had just joined the ship, he did not experience problems with new technology because he is young, fresh from school and is a child of the digital era. For the cadet, the complexity and uncertainty of technology depends on how accustomed an individual is to Internet use before joining the crew. To him, it was all about the ability of a person to deal with a computer.

"I think it depends on how technological you are and if you have used a computer before boarding a ship. Because if you have... not used any electronics then having to use it, I think you'll get lost. Yeah! If you're used to using technology, it's easier to adapt and see how the system works."

Another interviewee also believed that adaptation to new technology depends on the individuals themselves and whether the person uses technology at home or not. Although some interviewees feel comfortable about technology, they admit to being stressed from time to time due to still being in a learning process. When another interviewee was asked about the complexity of the technology and its uncertainties, he explained that his post of responsibility does not allow him to deal with a lot of technology. However, when necessary, he does so and when feeling uncertain, he asks his colleagues. Adaptability to new technologies also depends on personal traits, according to the interviewees. One crew member stated that he likes to take his time, be patient, focus, and learn how to deal with complex issues. This is a personal trait. He does not feel so stressed about things but instead tries to stay calm and figure things out.

"I'm good at taking the time to sit down, look at the system, look at drawings and read about it, because I think if you don't take the time, it can be overwhelming and you cannot figure out how it works and that will become a problem."

The interviewees also stressed the importance of teamwork. Many problems are solved when working together as a team. Sometimes the alarm would sound. When looking at the display, you will see many options that could be the cause, but only one is actually the problem. In this case, it is necessary to relax and take the time to study the problem with the help of colleagues. Another cause of stress detailed by an interviewee is the disparity between the simulated technologies studied at school and those in real service on board. He stated that it may cause frustration not being able to handle technologies due to being trained at school in different (and maybe older) systems. His advice was that educational institutions should upgrade in line with the advances in technology. The ability to adapt to new technologies is also perceived as depending on a crew member's past experiences. An interviewee explained that handling new technologies can be overwhelming for older colleagues, who have a lot of sailing experience using traditional technologies. For instance, the current use of touchscreen computers is difficult for them. It may therefore be stressful for those who have spent many years on traditional ships to adapt to complex technologies. Age was also stated as a factor in adapting to and understanding new technologies.

"I remarked to them, not only with this company, but also regarding other topics, such as alternative fuels and how to use the Internet. I remember that it depends on the generation and the age. For some it is easier, and for the older ones, because they are not so used to it, it might be difficult."

On the topic of how prepared they are to use these complex technologies, an interviewee stated that he feels unprepared due to the rapid advance of technology, which means he does not know exactly what to expect and prepare for. The only solution is to adapt to technologies as they come. The level of confidence in handling complexity also depends on the nature of the technology. An interviewee explained that as an electrician he would not be afraid of an electrical problem popping up, whereas he would be more afraid of an IT problem, since this would create more issues for him. This also demonstrates how the crew views IT issues as being more serious than electrical ones. Another issue that was raised is the fact that companies now struggle to find skilled staff, especially engineers. They sometimes call in retired crew members, who are mostly "old school" engineers and unaccustomed to these new complex technologies.

"The company struggles to find competent people. The company calls in retired people to help out from time to time because they can't find first engineers."

#### TECHNO-INVASION

The invasion of privacy due to new technological developments, especially after normal working hours, is perceived by crew members as the most prominent technostress factor in the maritime industry. Concern has been voiced at the invasion of technology in the private life of seafarers and the stress it causes, given that their workplace is also their home. In addition to the complexity of the new systems in the ECR and at the bridge, the nightly alarms are a major stress factor that the crew must handle during hours of work and rest, whether these alerts are false or real.

"Yeah! I think about the alarms. All our colleagues and even other seafarers have had this problem about the alarms because sometimes you get some notifications that are not real alarms but you just have to react and maybe interrupt your rest time or sleeping time to deal with something that maybe is not even relevant."

An interviewee reported that when he initially joined this ship and was first alerted by the alarms, he thought there was a fire incident. But he later understood that sometimes the alerts may just be caused by the wind or an electronic sensor. He thought this could be very stressful for a new crew member because sometimes they get notifications that are false alarms. The interviewee also stated that on his previous "traditional" ship, things were different and they had fewer false alarms. This gives reason to believe that alarm systems on modern ships are more sensitive. The interviewee explained that the new technology is based on monitoring systems that require continuous surveillance and are therefore more stressful to operate than on a traditional ship, because the crew is woken from their sleep, even during rest hours, to deal with alarms. When they return, they cannot sleep.

**"But when you have alarms during night-time, when you have to take care of everything yourself, it can be quite stressful."**

Alarms also cannot be ignored because something dangerous may, indeed, be happening, or it may be a warning of something about to happen. The interviewees reported that even when taking work shifts, they were always disturbed by the alarms during their resting/sleeping time. It is generally very difficult for the crew to cope with the invasion of alarms even during dinnertime. In this context, it should be noted that ECR engineers have an alarm system fitted in their room that notifies them of any issues that may occur. False alarms are especially very stressful because the crew needs to check the alarm for no reason. Sometimes the notification is just an observation. An interviewee explained that when the alarm sounds in his cabin, it is because something important has happened like a blackout on the bridge. The interviewee also noted that newer ships are fitted with more alarms than older vessels. Sometimes the alarms start due to minor issues. The workers must switch them off whatever the reason. They need to keep an eye on the systems and check everything every morning and additionally check three times during the day to ensure that everything is running smoothly.

**"When you have that alarm panel, and you have your duties, you have to always be on duty."**

An interviewee was asked if he got stressed by the notifications but replied that what stressed him was having to respond so fast, especially while executing other duties or being woken from sleep. Another interviewee noted the stress factor of being reminded of all the things he had to do.

In addition to the regular workload there are other systems down in the ship that must be monitored three times daily. Another interviewee explained how difficult it is to get six hours' straight sleep due to the alarms. Despite these alarm invasions, an interviewee was asked if he accepted sacrificing time to keep dealing with the technology and his affirmative response was "YES".

Another crew member reported not having to deal personally with the alarms but that other colleagues could call him in the event of an emergency, even during his rest time. Another crew member was asked if his alarm could be deactivated. He stated that it could but that he believed that the crew at the bridge is not allowed to do so. In general, alarms are not deactivated since this could pose danger in the event of a serious incident. An interviewee confirmed that sometimes alarms are deactivated when knowing that the issue would be something they needed to deal with later. The alarms are sometimes reminders of tasks that need doing, so some seafarers think they are still important.

**"If the engine triggers an alarm, the sump pump will have been running for a couple of hours. It can also be stuff like that. And you get a reminder from a system, and some engineering has to go unacknowledged. Okay, so it can both be serious and unserious, but the alarms are actually the same. So, read what it says to know if it's something important or just some type of reminder or something."**

Sometimes crew members need to rush to switch alarms off before continuing their duties, which makes work difficult for them as they may lose concentration on their principal tasks. But the alarms have become part of their job and they have adapted to working that way.

Most often, you receive multiple alerts from different systems, which is very frustrating for everyone. The researcher observed that crew members at the bridge spend time switching alarms off. When asked if the bridge crew had reported these issues to the company, the response was that no one would file such a report. A bridge worker had heard the same thing from others. No one files such reports since crew members need to follow the line of command and report issues to the Captain first. However, since the Captain is the voice of the company, the crew does not report issues to him because they do not feel they have his support. Subsequently, no reports are filed.

**"Sometimes I don't think we have good Captain support here. But I've heard stories about Captains not using these instruments on a daily basis. And then they are just overruling. Some decisions that everybody thinks are bad could be something like this. Although obviously, I really think we in this radio unit want this sound to go away and he's like, 'No', I think it's good that you get this."**

Some interviewees believed it should also be the duty of the Captain to ask the crew members whether anything is wrong. However, this generally does not happen. The Captain does not inquire, and the crew does not report either. The Captain also acknowledged that it may be stressful what with all the alarms. All the interviewees agreed that the alarms may sometimes be essential, but often they are not. Another example of the invasion of technology is seen when the Captain leaves his helmsman chair when the ship arrives at port and needs to focus on berthing the vessel but is distracted by the alarm.

"While we were about to arrive at our destination, and he was focusing on how to coast, the alarm started and he said the alarm might distract you from your main task."

Techno-invasion may also be manifested in a situation where the system assigns tasks to crew members that are not usually part of their job description. An interviewee explained that they received notifications from computer systems that give them additional tasks that are not really their duties.

### TECHNO-UNCERTAINTY

Techno-uncertainty occurs when constant changes and upgrades of technology result in feelings of frustration and anxiety. Techno-uncertainty is related to techno-anxiety, which refers to the use of computers or ICTs in ways that generate fear, apprehension and agitation in the user. It includes feelings of uncertainty when a person is required to carry out an action using ICT (e.g., pressing a button), and the related fear of losing information.[59] This study identified elements of techno-uncertainty among the crew of the studied ship. An interviewee was asked if he experienced stress from being unfamiliar with a particular technology. He responded by explaining that he does his best and that he asks his colleagues for help when not being able to deal with things alone. When asked if he feels compelled to change his work habits to adapt to new technology, he replied by saying he has no choice anyway. All workers must adapt to new technology.

Regarding the feeling of uncertainty, one interviewee expressed having issues with their computers sometimes, especially related to the lack of Internet connection, which causes confusion.

"We have some problems sometimes with our computer systems when we don't have Internet. Yeah. That can make us think, do we need to react to these things?"

The interviewees reported that something always goes wrong with technology and needs troubleshooting, which causes stress with workers when having to perform many tasks without the aid of technology. Sometimes they doubt which actions they are supposed to take.

"We have some old troubles with another technology, and in Gothenburg, where we are on shore power, sometimes that technology is messing things up. Yeah, technology, there will always be something not working correctly."

An interviewee was asked if he experienced stress from the uncertainty new technology can generate. His response was that his engineering background helps him a little since he possesses the basic knowledge and can therefore adapt easily.

Nevertheless, this is apparently not the case for all his co-workers. Another interviewee found it easy to adapt since he has worked on this ship since the beginning but was aware of the difficulty experienced by crew members who come from different types of ships. Sometimes, crew members get confused at alarms that sound similar to a fire alarm. Especially the first time they experience an alert.

"I was confused about it at the start, it's what I missed. Okay, they can give an alarm. Yeah. And this alarm it's like the same as the fire alarm. Okay, the first time when I was introduced to it, I thought it was a fire alarm. And then I found out I need to mute it locally here. Yeah, versus another fire alarm is just the same sound."

Sometimes, when crew members are faced with such new technologies and receive user instructions from their more experienced colleagues, the information they receive is not memorised easily. They forget things. An interviewee explained that a new colleague kept returning to him due to forgetting how the technology works, which was stressful for everyone. A cadet on the ship, who had the advantage of completing his cadet apprenticeship on the vessel, said he experienced no fear of operating the technology but that he had witnessed colleagues being very confused and stressed at always encountering new systems whenever requested to perform their duties. In some instances, a crew member would get tense when faced with a situation he could not handle.

"When I came down he was sweating, yeah, and we didn't know what he was doing. It was a complete mess. I had to fix everything when I got there. It also stresses me."

The interviewee explained that the new colleague found it very difficult to grasp everything in one week. There are instances where something goes wrong in the system, and they need to act quickly and do things manually.

"It didn't happen to me, but I've heard about it. If this online function doesn't work, then you have to do what it says in the tanks, and then manually in loadmaster, you can go to the store tanks, find all the data centres, then you have to press them in manually. And then every time you move water, you have to go in manually again."

An interviewee explained that they use different programmes although they still have old programmes on board. He expected the company to introduce a new system, which he believed will have a lot of sensors. When asked about the complexity of the technology and its uncertainties, one interviewee explained that in his position he is not permitted to deal with a lot of technology. When having to deal with technology, he would ask his colleagues for help when feeling uncertain. When everyone felt confident that he could operate a system, they would allow him to do so. Another interviewee reported having to be constantly available should something happen with the technology. Subsequently, he checks the electrical main boards every morning to see if all systems are operating normally. Techno-uncertainty may affect some colleagues more than others, depending on their background and age. An interviewee explained that technology sometimes breaks down and they need to fix the issue themselves.

"Sometimes the hardware can really be annoying, I think. Even if they are slow working, or sometimes they break down when you already have done major work. And then they crash and you need to do it again. Really annoying. Sometimes, yeah. Just frozen. And so many of these new technologies or new software and hardware can really be hard to work with sometimes."

### 5.1.3 TECHNOSTRESS INHIBITORS

#### TRAINING, NEW SKILLS ACQUISITION

Training and capacity building is recognised as a very important step towards the successful use of new technologies. The crew in this study shared their experiences regarding the training they receive in the use of technologies at the bridge and in the ECR. The central finding of this study is that crew members either receive very basic training or none at all. Interviewees working in the ECR stated not receiving any training.

An interviewee was asked if they at least received the basic training at the maritime school. He answered that although they acquired the basic knowledge they still needed to train themselves in the use of new technology installed on ships with the help of their co-workers.

When the crew members were asked if they had received adequate training, many explained that they learnt by doing. They do not receive proper prior training in the use of new technology installed on the ship, which causes a lot of initial stress. They do, however, use a Q&A tutorial in their learning process.

"We have these quizzes, for example, a quiz for these users, and you have a quiz for GMDSS, which is like communication and CGI for us. So that's more or less learning by doing. You learn quite fast. Just a couple of minutes. We have a lot of questions and through answering these questions you'll learn about how to use the systems. It's quite good, I would say, as I still know that there are a lot of functions that I definitely don't know as a second officer. I'm not making the routes, and I'm not updating the charts. So, we have, like, how to do this in our computer, so if I have to do it then I can always go through this manual, which should be fine but still functions."

Some interviewees think that learning by doing is not a quick way of learning, especially if your job does not require you to work with these technologies on a daily basis. They believe that there is a need for proper training. An interviewee explained that he feels a need for training and that he is behind on the technological development.

"I think it would need more training. Yeah, actually, sometimes I feel like I am far behind the technology. But I think that is because of my work position. I'm not working with the systems every day. I'm welding and constructing and repairing, so I don't need the technologies every day. Yeah. So that when the technology takes five steps forward, maybe I'm only at step one or two. Yeah. So, I'll never reach that point by learning by doing, I think."

Another interviewee, who has a background in mechanical engineering, explained that at school they had not dealt with anything related to his current tasks. He was taught the basics but the rest he has learnt by himself with the help of his co-workers.

Teamwork is what keeps the crew knowledgeable and they learn from each other. An interviewee explained that whatever problem they encounter, they deal with it as a team. They ask each other and fix their issues. Some crew members also believe that maritime schools do not have sufficient funding to upgrade their training to meet the rapid technological development. Subsequently, student do not learn about new technologies.

Even when schools attempt to teach new technologies, the OSH impact of the systems on workers is neglected. An interviewee explained that nothing is taught in school regarding the stress that new technologies may cause or about the development of technology in the maritime industry as such. Another interviewee was asked if they received any training in stress management. He explained that they received some training in cybersecurity but not technology stress.

An interviewee believed that maritime schools are still far off target. He believed they follow a political agenda that is difficult to change. Another interviewee explained that he is still learning to manage the systems, although he has been stationed on the ship for several years. He recommends that schools adapt to technological development, which he sees as an advantage, such as combining charts and radar on the same screen. Another interviewee believed maritime schools should reform given that they have been so slow at implementing changes in capacity building and training regarding new technologies.

It was also remarked that some crew members, who had previously worked with other maritime companies, had forgotten the training they had initially received due to not practising their knowledge. An interviewee explained that she was trained at Maersk but does not remember anything from her training there. Another interviewee believed that any new technology should require the provision of training and manuals to avoid stress.

"I believe that every week where we get something new on board, there should also always be some kind of training or manual."

Another crew member stated that only being issued with a manual is not enough and that proper training is required. Perceptions regarding training differed. While some crew members believed that prior training is essential, others do not feel a need for training. One crew member, who did not feel he needed prior training, stated that crew members have time to practice while on bridge duty. Most of the crew had not previously worked on a ship with modern technology but when serving on a ship like the studied vessel, they adapted and eventually learnt.

"We don't actually take courses to learn different technologies on different ships. Yeah. So that's kind of an issue, but you work with it every day. So, of course, you will learn eventually. Yeah, it could be more operational focused."

An interviewee stated that it initially had been stressful for him to work on the ship but that he had learnt a lot from constantly asking his colleagues. Many of his co-workers said the same.

An interviewee explained that he was not granted time for training. He had called the company for a job and after two days he was on board this ship and had not received prior training in the technology, which he initially found stressful. On the issue of seafarers working on a fixed contract, one interviewee was asked if enough time was given to study and upgrade their knowledge of new technology at their workplace. The crew member replied that they are given no time for such activities and need to learn during their spare time, which means they are not paid for their training. Most also preferred to spend time at home with their families rather than undergoing training. An interviewee explained that while working on a traditional ship they had been oblivious of the speed of technological development, which is evident on newer ships like the one they were working on now. In addition, engineers often change their job due to technological development. He believed that engineers should continuously upgrade their skills to stay competitive in the market.

"Out here, we don't see it if you're on an old ship. You don't see the new technology as much as you do on a new ship. And you can have a hard time developing yourself. So, I also think there are a lot of engineers who change their position every five years or something like that. Especially new engineers should upgrade themselves to be with the times."

Another interviewee was asked if he ever discusses with his colleagues the necessity of upgrading and training to stay competitive. He replied that most often he does, especially when they see that many engineers now prefer to work onshore rather than on ships.

"Sometimes we do. I also talked about it with another Chief Engineer, and was also asking why we change jobs as often as we do. Yes, I think that's one of the issues. Because we need to move with the times."

Some crew members, who had received some level of training, indicated that what they learnt at school does not reflected reality. They were taught the basic but not about advanced technology. Some crew members reported everything at school being manual, whereas when arriving on board, everything is digitalised. One interviewee believed that maritime schools had limited resources and could not afford to update equipment. He stated the example of the school he had attended having a very old radar and simulator. Another crew member explained that serving as a cadet for the company had been very beneficial. It helped him a lot, whereas other colleagues seemed stressed at having to learn to operate the systems. An interviewee explained that officers are only given one week to learn everything, which is not enough.

"A year before I became an officer, people coming from other companies were being told: 'Now you spend a week with me, and I will show you everything and then you're going to be on your own.' The time is not enough."

The interviewee recommended that maritime companies should focus less on short-term profit and that proper training would be beneficial to all. He suggested that at least four weeks should be allocated to training so newcomers experience less stress and in turn cause less stress with their co-workers. One interviewee explained that he was a trained mechanic and received 20 weeks of training to adapt to the maritime field, but even with this much time, he did not really feel ready. The first days on board had been so stressful for him. He had not felt well prepared to take on the responsibility. The interviewee explained that even though this ship is new, other ships have more advanced technology. Another interviewee expressed the need for more training but said that if such training were to take place in his spare time, he would rather spend time with his family. He is not paid for training.

"I could do a lot of training. I think I need to update myself. It might not be necessary for my position, though, but that is more for my own sake. Okay, to carry on with the new system as well, but I think it's difficult when you're already away half of the time and some of the seafarers more than half the time. Yeah. I think I don't want to spend my free time on education. For how long do you stay on the ship. Before we go home. It's only 14 days."

Another issue is that maritime schools are located in big cities. Seafarers living far from these cities find it difficult to gain more training.

"I think that's a big issue. That education is in big education centres, and yeah. Because if it were different; if they were still in the smaller cities around, I think I would have had more education on my resume."

Sometimes training can be conducted while seaborne. But one interviewee maintained that such onboard training may not be effective, especially if only provided for a single day or for a few hours. Even combining one week of training with one week of land leave is not enough since seafarers tend to forget all they have learn when returning home. Moreover, the interviewee believed that maritime companies are not willing to pay for the training of the crew. He explained that a company he previously worked for provided three weeks of paid training, although he was unsure that would be the case with most maritime companies and remarked that his current place of employment does not grant them very much time for training.

One crew member explained that the factors preventing adequate training include finding time for training and being able to access a training facility close by. The Captain explained that the company has a one-week training policy for newly recruited crew members. From the researcher's understanding, the training of the staff is integrated with their main duties. The Captain explained that their principle is for crew members to complete their training as fast as possible. One interviewee was asked if there was any discussion at the maritime schools on upgrading their training. He answered that although there was such a discussion, he believed the schools would always lag behind the technological development. The type of training matters, too. An interviewee believed that the entire crew needs training in computer use. This should be a basic skill for all maritime workers since the technological development embraces digitization and automation.

"I think they need a better understanding of how computer systems are working and have a better feel for technology."

The Captain explained that companies now struggle to find competent workers, especially engineers. They sometimes call in retired people to help on board.

### RAISING AWARENESS

Technostress is a subject with wide implications since technology is used in every field. However, the extent to which workers are aware of the OSH consequences of technology is questionable. Seafarers in this study were asked whether they received any training in or information about technostress. One interviewee explained that at his previous workplace, senior managers received training in stress management but not about technology related stress. Another interviewee remarked not having received any training since the company principle is that those who have received training in stress management must train their colleagues. However, this knowledge sharing does not deal with the use of technology. Webinars about mental health and fatigue are usually organised but they do not deal with stress-related issues. Interviewees who were graduates of maritime schools reported not having received stress management training even at school.

Moreover, addressing a case about harassment on board a Danish ship, one interviewee reported having taken part in a webinar about bullying and harassment and furthermore believed that the company will include stress management at some point. Another interviewee suggested that maritime companies should be less concerned about profits and that a proper training in mental health and stress would be beneficial to everyone in the sector. The crew members reported that most of the training obtained is technical in character and that schools do not provide soft knowledge. Another interviewee explained that they had taken part in a webinar from their staffing agency about mental health issues resulting from COVID-19. The Captain explained that crew members do not express their mental health concerns to management. Culturally, some nationalities fear that if they do so, they will risk losing their jobs. He said that if he inspected the cabins of his crew, he felt sure he would find anxiety medication but that crew members would never admit to having such issues. The Captain explained that crew members of some nationalities have a work culture of obedience and do not express dissatisfaction.

"The crew doesn't express their stress or feelings - the 'yes Sir' culture, because they are scared to lose their job."

# 6 CONCLUSION AND MAIN FINDINGS

Like workers in other industries, seafarers face changes to their work organization and labour relations. They are under increased pressure to meet the requirements of the modern global workplace. Understanding the stress caused by technology and the coping processes seafarers experience when dealing with technology is vital to improving their performance and to ensuring their commitment to the continued use of ICT. As new technologies transform seafaring, this study aims to shed light on technostress as one of the mental health issues that seafarers face from the pressures of technology.

As a result of the analysis of interviews conducted by the author with the crew of the Danish flagged vessel, the following recommendations have been made within four areas: regulations, awareness, training and discussions with social partners:

| | |
|---|---|
| 1 | **Regulations:** Although there are international and regional regulations in place regarding stress in the workplace in general, there is no regulation governing technostress internationally, regionally, nationally or even on an industry basis. Subsequently, there is no Danish maritime regulation regarding technostress. However, it is important to recognise this source of stress and its psychosocial impact on workers, especially seafarers. |
| 2 | **Awareness:** Although technostress is proven to affect the mental health of seafarers, the victims of such stress seem unaware of the gravity of the issue. It is therefore necessary to promote awareness of technostress through various means, such as conferences, seminars, and expert meetings, so research results can be disseminated throughout the maritime community. |
| 3 | **Training:** For new technologies to be properly applied, seafarers must be adequately trained before joining new ships. Training enables the users of these technologies to be confident during routine operations, thereby preventing techno-anxiety. Seafarers should be granted time and financial support to receive training. In addition, maritime schools should update their curricula to align with modern technologies. |
| 4 | **Discussions with social partners:** the involvement of social partners in the entire process of the adaptation of new technologies is essential. Such discussions allow seafarers to express their feelings regarding the use of new technologies, which they are often unprepared for. |

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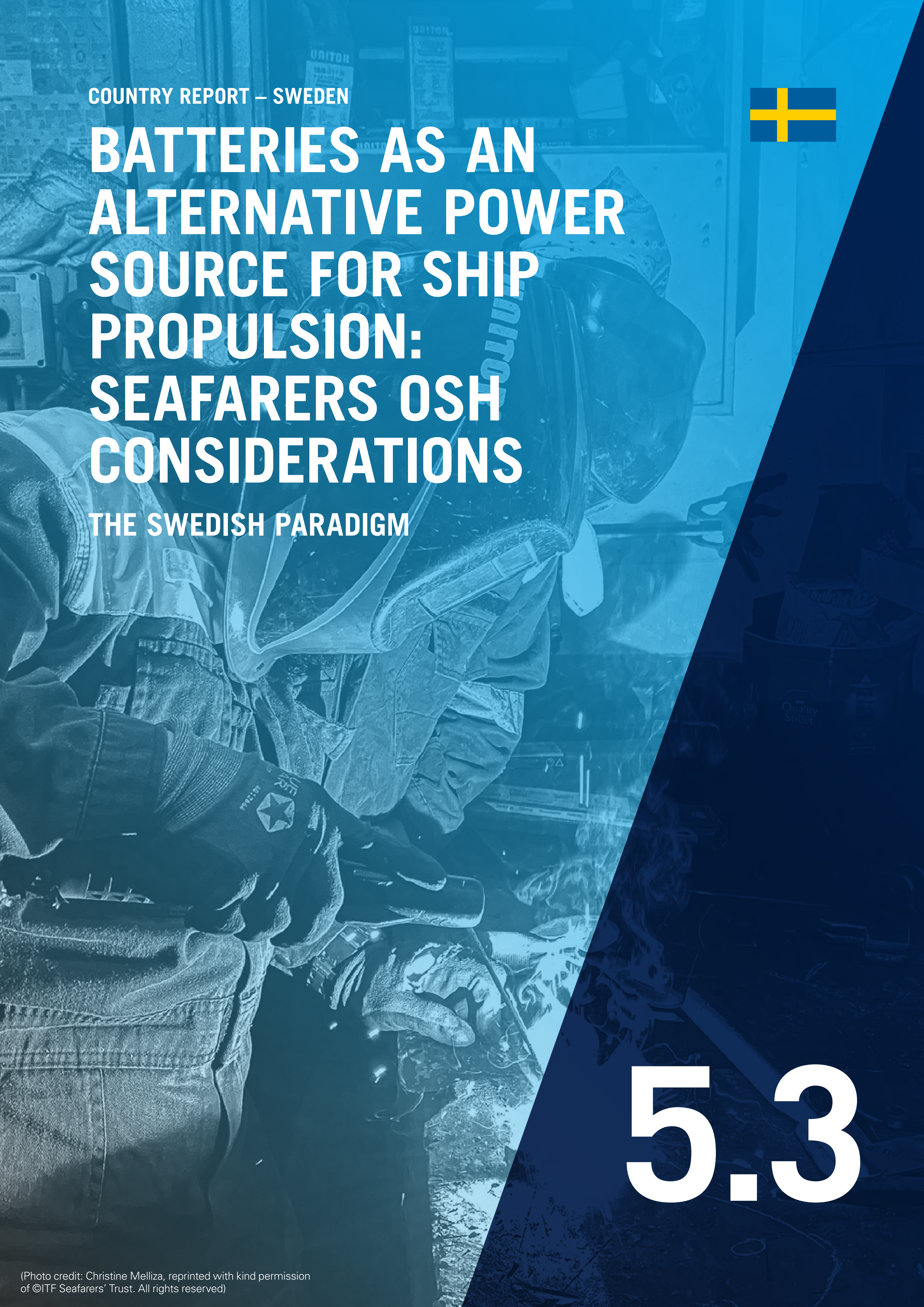
COUNTRY REPORT – SWEDEN

# BATTERIES AS AN ALTERNATIVE POWER SOURCE FOR SHIP PROPULSION: SEAFARERS OSH CONSIDERATIONS

## THE SWEDISH PARADIGM



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# 1 EXECUTIVE SUMMARY

This country report is one of a series of four such reports on the impact of new technologies on the Occupational Safety and Health (OSH) of seafarers. This report centres on the use of battery-powered propulsion as an alternative to fuel and its impact on the OSH of seafarers. A Swedish-flagged ship is studied as an example. The report is subdivided into four main sections: 1. The concept of a Just Transition and how this case study fits into this concept; 2. The impact of battery-powered propulsion on the OSH of seafarers; 3. OSH regulations regarding battery-powered propulsion at sea (international, regional and national); 4. The Swedish context as represented by a Swedish-flagged ship. A field study was conducted on board the ship to gather data based on a semi-structured interview guideline.

As a result of this case study, the below recommendations have been developed. These recommendations may potentially also be applicable to the adoption of technologies other than battery power.

| | |
|---|---|
| 1 | The inclusion of seafarers in the discussions regarding the shift to battery power is highly important. Since the technology has already been implemented, any redesign or modification of the current design should include inputs from current users and those who operate the batteries on a daily basis. |
| 2 | Ensure that workers (ratings) have a “real and effective” say in the development and implementation of technology. Governments should develop regulations to clearly define the role of workers in the entire process. |
| 3 | Increased social dialogue would be important. Shipping companies should work more with social partners and other stakeholders to create awareness among workers about alternative fuels and their potential use. The sharing of information is a very important factor and relies on collaboration between different actors in the sector. |
| 4 | With the introduction of battery-powered propulsion, all crew members should undergo electricity and high voltage training, regardless of whether they are working with batteries or not. |
| 5 | With other fuel alternatives further specific training would be required depending on the choice of technology. The focus should be on adaptive learning and the value of training in the real world of working life. |
| 6 | The International Labour Organization (ILO) and International Maritime Organization (IMO) should urgently develop regulations on the use of specific technologies already present in the market. |
| 7 | Changes in employment terms and duties may be necessary (e.g. some seafarers may have to help with the change of batteries – see the case study). Regulations should be clear and prepared for any additional adoption of new technologies. |

# 2 INTRODUCTION

Climate change has brought to the forefront the responsibility of governments and companies worldwide to achieve net-zero emissions relating to greenhouse gasses by 2050 in order to meet the requirements of the Paris Agreement. To stay in line with the Agreement, the shipping industry has pledged to reduce its emissions and has developed several initiatives in this direction, such as using alternative fuels, including Ammonia, Hydrogen and lithium-ion batteries. However, the introduction of these alternative energy sources poses various concerns, particularly in respect to their impact on the OSH of the workforce. This report analyses the impact of lithium-ion batteries on the OSH of seafarers and builds on an extensive study of practices in the use of batteries on ships and their impact on the OSH of seafarers. This report aims to provide an overview of existing practices, challenges, and possible solutions to better manage the transformation of jobs and working conditions brought about by new technologies, such as lithium-ion batteries as an alternative to fossil fuel. To this end, this study takes a closer look at the Swedish case of the use of lithium-ion batteries on board ships. It assesses the associated risks, preventive measures, emergency procedures, accident reporting, seafarer participation and seafarer training in the use of battery power on board ships.

A literature search was conducted to identify current cases of battery power for propulsion within the Swedish context. Foresea, a company flying the Swedish flag and operating battery-powered vessels, was shortlisted for the case study based on its experience in applying this technology and the availability of the personnel and the management of the ship for data collection. Guidelines for structured interviews were developed and reviewed according to the WMU Research Ethics Committee procedures. Qualitative data was collected from seafarers on one of the company's ships (M/S Aurora of Helsingborg). Our researchers spent time with the seafarers at their workplaces and visited the installed batteries on board. In addition, the researchers engaged with the Swedish Transport Agency (Swedish: Transportstyrelsen), technology developers and an expert in trade union affairs.

The ultimate objective of this research study is to ascertain the effectiveness of implementing the relevant regulatory provisions regarding the OSH of seafarers pertaining to the use of battery power on board vessels and to survey the general feeling of seafarers about the shift from traditional fuel-based to battery-powered propulsion. The questionnaire was divided into six sections based on the ILO Guidelines for implementing the occupational safety and health provisions of the MLC 2006 Convention.[1] These include risk assessment, accident prevention, emergency procedures, the participation of workers, accident reporting and the necessity of training. A total of twelve interviews were conducted. The data was analysed using the Atlas.ti qualitative analysis tool.

This report does not have the ambition of providing an exhaustive inventory of existing practices regarding OSH in relation to battery-powered vessels. Rather, it aims to provide an example of practices in a country like Sweden, recognized for its investment in technological solutions to protect the environment.

# 3 A JUST TRANSITION

The importance of marine fuels for the overall operation of ships is evident. Marine propulsion has evolved from heavy fuel oil (HFO) and Marine Gas Oil (MGO)[2] containing high hydrocarbon levels compared to other recently adopted alternative fuels, such as LNG, hydrogen, ammonia, and batteries, known collectively as "clean fuels."[3]

Introducing these new technologies as alternative power sources requires drawing up new safety procedures and training workers in understanding the related safety and health challenges. In the maritime industry, initiatives in testing are being carried out on new fuels, such as hydrogen enhanced fuel and ammonia.[4] Fuels with high hydrocarbon content undergo combustion to produce exhaust gases with high concentrations of $NO_x$, $SO_x$ and $CO_2$.[5] Despite marine fuel being essential for the operation of ship propulsion and auxiliary machines, its negative impacts on the environment and society are considerable, making the use of marine fuels an issue of global concern.[6]

The most significant impact of marine fuel use is the emission of GHGs with devastating effects on climate change.[7] According to the third IMO GHG study, in 2012, $CO_2$ emissions from maritime transport amounted to around 938 million tonnes of $CO_2$ annually, responsible for about 2.6% of global $CO_2$ emissions.[8] Failure to stabilize or mitigate global emissions of $CO_2$ and other greenhouse gases may lead to economic losses amounting to at least US$2 billion per day by 2030.[9] The study further demonstrates future projections as representing a significant potential increase if immediate mitigation measures are not developed and implemented. For instance, shipping emissions could, under normal circumstances, increase between 50 and 250% by 2050, therefore compromising the Paris Agreement of 2016, which aims to keep the global temperature rise below 2°C, and even as low as 1.5°C, above pre-industrial levels.[10]

Although the Paris Agreement does not include international shipping, the IMO has complemented the Agreement with its Initial GHG Strategy,[11] which expresses IMO's commitment to reducing GHG from international shipping this century. In line with the vision of IMO to confirm this binding commitment, the total annual GHG emissions is envisaged to be reduced by at least 50% by 2050 compared to 2008 and eliminated as soon as possible. The strategy, since its adoption, has sent shockwaves across the maritime industry, with shipowners and seafarers targeted to become an integral part of its implementation. During the MEPC 72, in which the strategy was adopted, IMO Secretary General, Ki Tack Lim, declared his trust in the ability of the IMO member States to continuously develop actions that would contribute to the reduction of GHG from shipping, and encouraged them to work together through the newly adopted GHG strategy designed as a platform for future actions.[12] The IMO initiative also joins other global initiatives directed towards achieving GHG reduction, such as the United Nations Sustainable Development Goals (UNSDGs) and, more specifically, SDG 13, which expresses the need to fight against climate change and its impacts. In addition, another target relevant to GHG emission reduction is target 13.2, which calls on States to integrate climate change measures into national policies, strategies, and planning. To reinforce these initiatives, the European Parliament voted on 22 June 2022 to extend, for the first time, its carbon market to include shipping and road transport in the Emission Trading System (ETS). This took place two weeks after the vote on expanding the coverage to all departing flights from the European Union (EU). This initiative is considered a historic expansion, leaving it to national governments to adopt an equally ambitious position.[13]

All these measures are in line with the evolving Just Transition concept advocated for by the 2015 Paris Agreement. The Just Transition concept focuses on the transition out of high-carbon activities into the green economy, seeking to avoid harm to workers, communities, countries and regions, while maximising the benefits of climate action.[14] In this regard, the Paris Agreement recognizes that policy implementation should take into account "the imperatives of a Just Transition of the workforce and the creation of decent work and quality jobs".[15] This implies that over the course of transition, the health and wellbeing of workers and the community should not be compromised.

To ensure the placement of workers' rights and the access of developing economies to zero-emission and zero-carbon fuels at the core of policy decisions, ILO adopted Guidelines for a Just Transition towards environmentally sustainable economies and societies for all[16] in order to provide a framework adopted through tripartite consensus that countries can make use of in their steps towards a low carbon transition. Building on these demands, a Just Transition Maritime Task Force was created and funded by the International Chamber of Shipping (ICS), the International Transport Workers Federation (ITF) and the UN Global Compact. Among aspects advocated for by the task force is capacity-building. Seafarers are expected to be trained and equipped with the appropriate skills for a Just Transition in the maritime industry. Especially highlighted is the need for seafarers to acquire skills to handle future green fuels. In support of the implementation of the Just Transition concept in the maritime sector, the UN Secretary General affirmed the need for global collaboration from stakeholders, given the international nature of shipping, and in particular that no one should be left behind.

Among other aspects, the IMO Secretary General, Ki Tack Lim, highlighted the need for skills development, implying the need for "green skills." He called especially on seafarers to become an integral part of this transition, given the important position they occupy at the core of the shipping workforce. The Secretary General also highlighted the importance of the Just Transition Maritime Task Force in IMO's current work, especially in the envisaged comprehensive review of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (the STCW Convention).[17] Thus, according to ITF, a Just Transition to sustainable shipping should warrant its establishment on eight solid principles: be ambitious, timely, democratic, safe, equitable, diverse and funded, and improve seafarers' working lives.[18]

Therefore, the transition towards low-emission shipping transport is imminent, and as IMO seeks to mould shipping's decarbonized future, the maritime industry is looking to shift from fossil fuels to alternative power sources. Among the catalogue of alternatives being tested in a bid to mitigate GHG emissions is the use of lithium-ion batteries[19] on board ships.

The use of batteries is a welcome development in the shipping industry and is being applauded for its GHG reduction and climate change mitigation potential. Lithium-ion batteries can either be used on their own or as a hybrid solution involving fuel sources. The case for lithium-ion batteries is made by industry actors such as DNV, confirming that "all electric and hybrid ships with energy storage in large li-ion batteries can provide significant reductions in fuel cost, maintenance and emissions as well as improved responsiveness, regularity and safety."

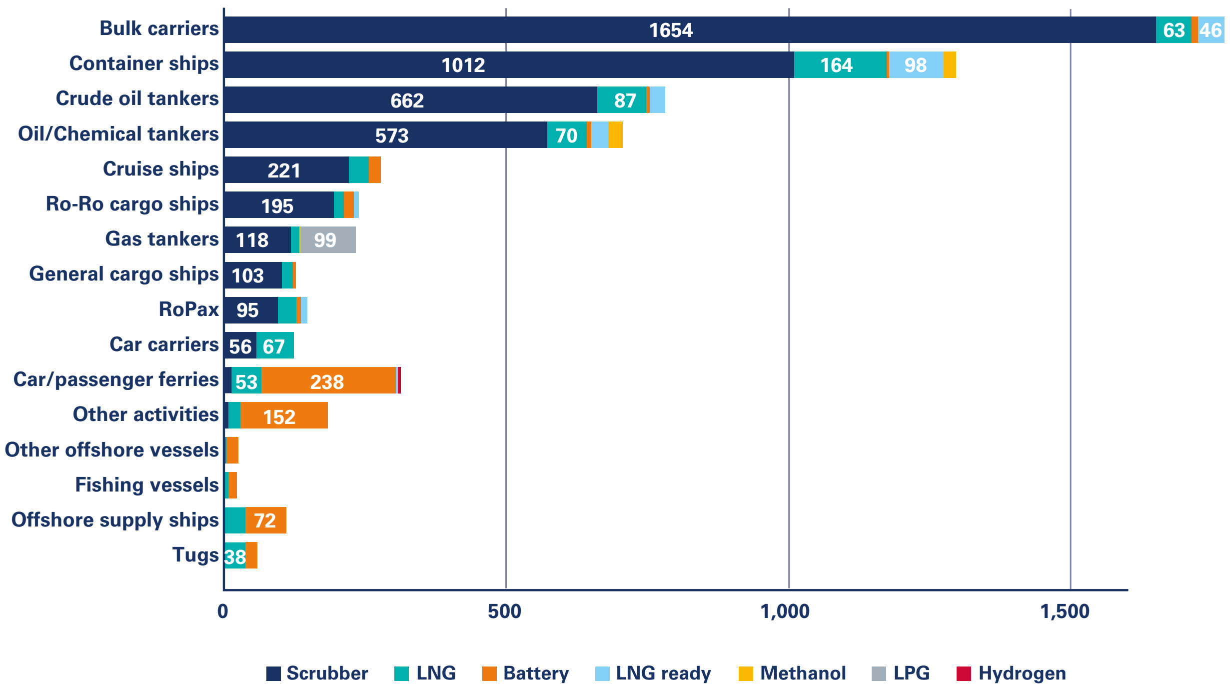
# 4 INTRODUCTION OF BATTERY SYSTEMS ON SHIPS

Electrified drives were first introduced for ships at the turn of the twentieth century, notably on warships and passenger lines.[20] Batteries on ships have been a common element for quite a while, especially with the machinery. Electric equipment has played an essential role in supporting a ship's different functionalities, including providing start-up power for emergency systems, safety equipment, communications, and other less energy-intensive requirements. Moreover, battery power can act as a backup for generators, reducing the need to draw on spare generator capacity. According to a study,[21] the environmental savings from the use of batteries to reduce the usage of generators is estimated to be approximately 500 tonnes of fuels saved and about 1,500 tonnes of reduced $CO_2$ emissions, which corresponds to the annual emissions of around 600 cars.

During recent years, the electrification and hybridization of ships has increased due to tighter emission regulations, volatile fuel prices, a fast-changing market for the protection of the environment, and the advancement of lithium-ion battery technologies. Naturally, the increase depends on many factors at international and national levels, such as the cost of the Energy Storage System (ESS), the availability of charging infrastructure, adequate regulation, social acceptance, and the labour market. It also depends on the development of technologies in other industries driving the market, such as the automotive sector and power industry. The maritime industry may also benefit from technology transfer from the military, which develops large-scale rail guns that require efficient and large energy storage units.[22]

Today, around 4,000 ships, the equivalent of 5% of the global fleet,[23] are powered by electric means in diesel-electric propulsion, hybrid propulsion and all-electric battery drive systems (see Figure 5.3.1).

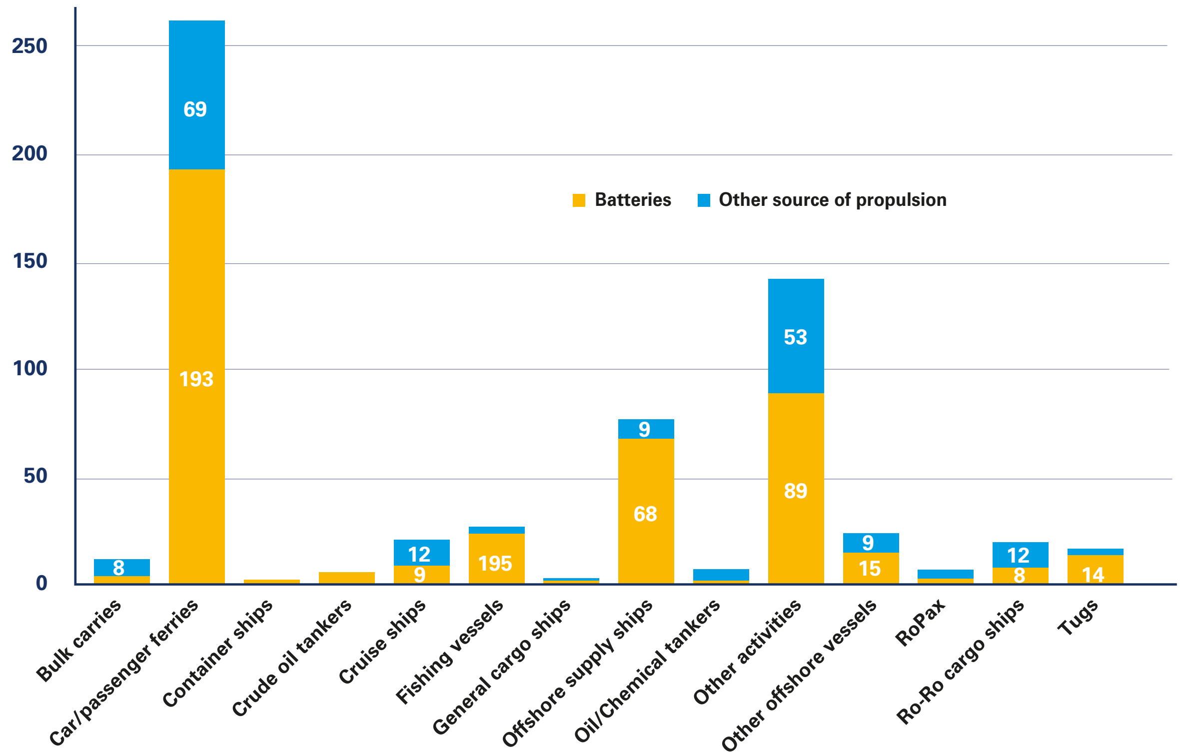
FIGURE 5.3.1 Total number of battery-powered ships




Source: DNV, Alternative insights, 2022

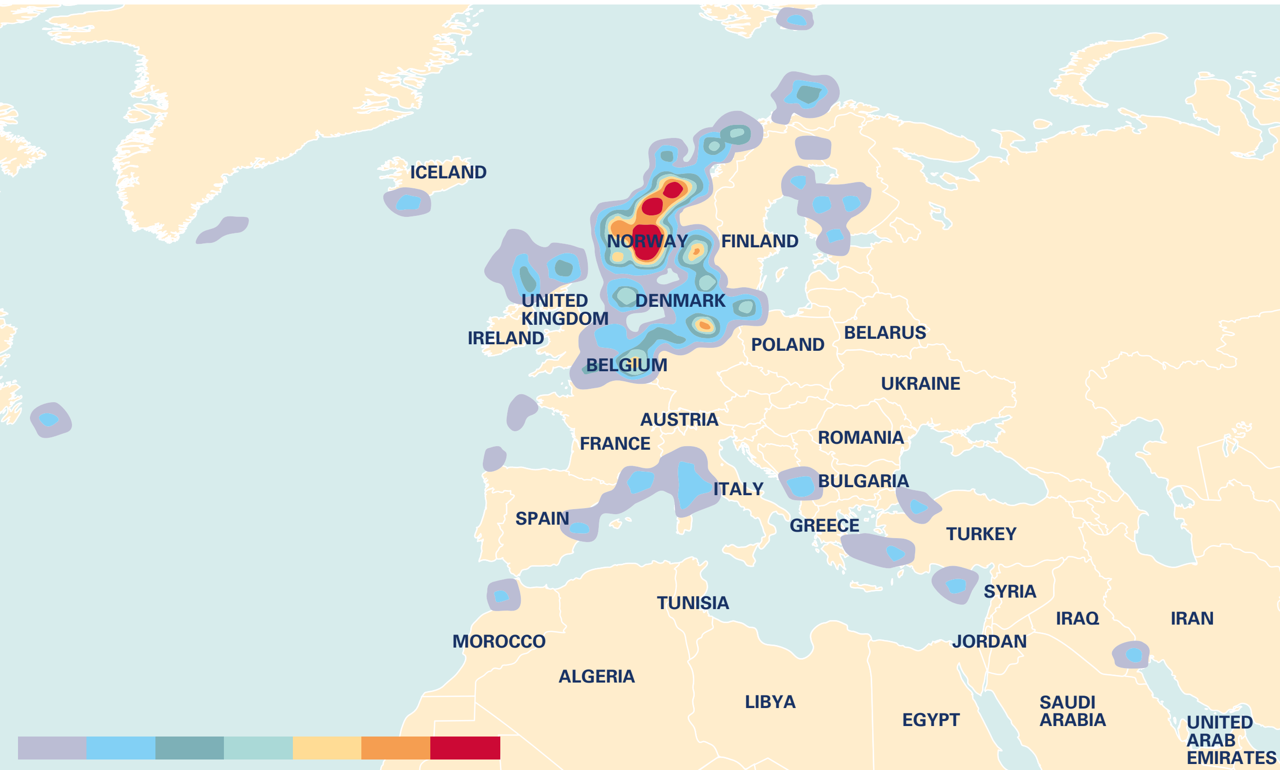
Short-distance ferries seem to be much more advanced in introducing electrification than trans-oceanic ships and cargo vessels (Figure 5.3.2). The highest concentration of electric ferries is in the Scandinavian countries, including Norway, Denmark and Sweden, as shown in Figure 5.3.3. Other countries, such as Canada and New Zealand, are also supporting initiatives for electric short-distance vessels.

FIGURE 5.3.2 Number of battery-powered ships by ship type




Source: DNV, Alternative insights, 2022

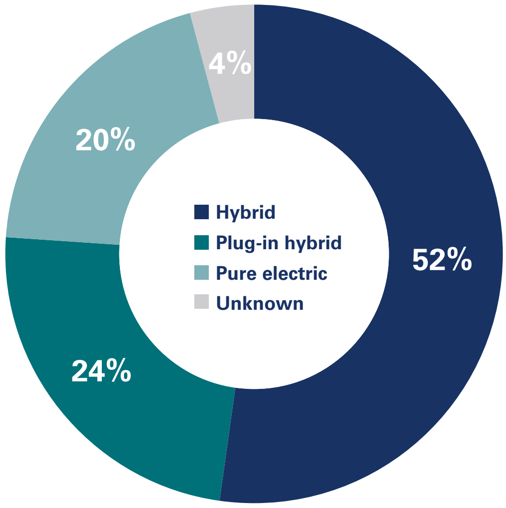
FIGURE 5.3.3 Concentration of battery-powered ships




Source: DNV, Alternative insights, 2022

However, out of the total number of vessels operating around the world, only very few are purely electric (Figure 5.3.4).

FIGURE 5.3.4 Battery application




Source: DNV, Alternative insights, 2022

The process of electrification may involve several steps. Generally, the first step is hybridising the existing ship power systems.[24] The benefit of this method is to reduce the acquisition costs and lower the charging requirements.[25] This method also helps to modify existing vessels.[26] Therefore, in addition to vessels with battery-powered propulsion, there are also some examples of hybrid-electric ferries.

In summary, there are two kinds of application of batteries for propulsion:

**1. BATTERY-ELECTRIC:**

- Large ferries (around 1,000 passengers, 150 cars) serving short distances (up to 5 km)
- Medium-sized ferries (around 300 passengers, 50 cars) serving short and medium distances (up to 40 km)
- Fast catamaran ferries (250 passengers, no cars) operating commuter or tourist routes (up to 90 km)

**2. HYBRID:**

- Large ferries (around 1,000 passengers, 150 cars) serving longer routes (over 60 km)
- Commuter ferries serving fixed routes, electric or switching to electric in some cities to reduce air pollution.

In the following section, an example of a Swedish hybrid ferry is provided as a case study.

# 5 POTENTIAL IMPACT ON THE OSH OF SEAFARERS BY BATTERY-POWERED PROPULSION

As much as battery-powered propulsion offers environmental benefits, the impact on the OSH of seafarers is of great and ongoing concern. According to ILO, OSH is "the science of the anticipation, recognition, evaluation and control of hazards arising in, or from, the workplace that could impair the safety, health and wellbeing of workers."[27] This includes the promotion and maintenance of the highest degree of physical, mental and social wellbeing of workers in all occupations. It also takes into account the possible impact on the surrounding communities and the general environment.

The international community has also noted the importance of OSH for seafarers. In this sense, the ILO has set standards through the Maritime Labour Convention (MLC 2006) to protect seafarers during their normal operations on board vessels. In addition, the ILO has considered OSH as one of the key policy areas to address the three dimensions relating to Sustainable Development[28] – i.e. economic, social and environmental – in a balanced and integrated manner. The MLC 2006 identifies areas in which OSH policies and programmes are to be adopted effectively, implemented and promoted on ships, which include OSH protection and accident prevention.

Specifically, the MLC 2006 Regulation 4.3, entitled Health and Safety Protection and Accident Prevention for Seafarers, contains standards and guidelines to ensure seafarers' work environment on board ships and promote OSH. In addition, the IMO, through the International Safety Management Code (ISM), has adopted safety measures for seafarers. The purpose of the ISM Code is to provide an international standard for the safe management and operation of ships and pollution prevention. Therefore, it is crucial to consider the impact on the OSH of seafarers when adopting battery-powered propulsion as a new technology. While the shipping industry already promotes and implements battery power, research on its potential impact on the OSH of seafarers still trails behind.

Several studies[29,30,31,32,33,34] have demonstrated the importance of battery-powered propulsion as an alternative to fossil fuel in terms of fuel-savings and the potential for mitigating environmental pollution. However, the risks seafarers face with respect to OSH and the impact on their working conditions associated with battery use on board vessels have barely been investigated.

It should not be underestimated that the choice of power source for the operation of a ship's propulsion system and auxiliary machinery indeed does have an impact on the ship's working environment and, consequently, the health and safety of seafarers. This choice of power source also affects their working conditions and duties related to the daily operations of the ship and poses occupational hazards and risks of illness.[35] Therefore, when choosing the type of power source for propulsion on ships, it is crucial to consider the OSH of seafarers.

## 5.1 HAZARDS RELATED TO THE USE OF LITHIUM-ION BATTERIES

**"THE TRANSITION TO ELECTRIC IS ONE OF MONUMENTAL SCOPE AND IS BEING CARRIED OUT WITH UNPRECEDENTED (AND NECESSARY) SPEED TO ADDRESS CLIMATE CHANGE. THE ANTICIPATION, RECOGNITION, EVALUATION, AND CONTROL OF HAZARDS ASSOCIATED WITH THIS TRANSITION WILL BE OF CONSIDERABLE IMPORTANCE AND A CHALLENGE TO OCCUPATIONAL HEALTH AND SAFETY PROFESSIONALS." (CAMPBELL, 2022)**

Most electric ships use lithium-ion batteries. These batteries contain dangerous compounds and elements that are harmful to humans when in contact with them. However, there is still uncertainty regarding the materials that will be used in future vehicle-powering electric batteries.

As discussed in the open literature within the context of the environment, health and safety, it has been noted that some potential lithium-ion battery materials are toxic, carcinogenic or are capable of undergoing chemical reactions that produce hazardous heat or gases. Toxic materials include lithium, nickel and arsenic compounds as well as dimethoxyethane. Carcinogenic materials include nickel, arsenic and cobalt compounds as well as copper and polypropylene.[36]

Manganese compounds also effect human health, such as chronic manganese poisoning, which can damage the central nervous system and lungs. Chronic manganese poisoning usually occurs after manganese dust is inhaled over several years, but may occur after three months of heavy exposure. Lithium compounds present a hazard both as electrodes and as the electrolyte in lithium-ion batteries.

Although lithium-ion presents fewer hazards than lithium metal, it has an acute toxicity and chronic effects on the central nervous system as well. Moreover, the high reactivity of lithium metal makes it a health hazard. Hydrogen, a flammable gas, is formed from the reaction between lithium metal and water. It also reacts with moist air and several other substances. Such reactions release heat and, in some cases, hazardous products are generated. In addition, humans may suffer severe chemical burns when in direct contact with lithium metal. Workers are exposed to lithium-ion mostly during the manufacturing of lithium-ion cells, either from the positive electrode material or from the electrolyte salt. However, after the assemblage of the cells, exposure to lithium-ion is reduced and may only occur should cell containment fail. Similarly, in the unlikely event that the lithium metal is formed during cell cycling, exposure to the metallic form could occur should the cell container fail or during recycling.

In the automobile industry, similar discussions exist regarding the impact on the OSH of workers resulting from the transition to electric vehicles. The presence of a high-voltage direct current battery supplying power to the motor or motors has been identified as a potential new hazard resulting from this transition.[37] Moreover, electric shock is known to most often occur when the battery pack has been damaged and the engineered safety features have been disabled through damage to the electrical isolation system. Initial responders are at the highest risk of electrocution through exposure to the destroyed batteries. Note has been taken that, currently, battery damage would most likely occur during vehicle crashes. However, experts have noted that due to growing use of electric vehicles for commercial purposes, there is greater likelihood of more frequent damages due to wear and tear. As a result, companies using electric vehicles are advised to adopt safety precautions and determine the level of response and maintenance measures to be adopted to handle potential hazards.

Thermal runaway is a potential hazard since overheating due to individual battery cell damage may lead to fires. This was the case reported on board a Norwegian battery-powered sightseeing vessel, Brim Explorer, located at the time around Fredrikstad. The vessel had two battery rooms on board with a total of 790 kWh of lightweight batteries installed. Reports suggest that one of the battery banks overheated and triggered a fire. There were no passengers on board at the time of the incident but four crew members were safely evacuated and the ferry was towed ashore.[38] Another serious lithium-ion battery fire incident occurred in the aeronautic industry aboard a Boeing 787-8 airliner in 2013. The National Transportation Safety Board stated that this was partly due to thermal runaway caused by manufacturing defects in the battery.[39]

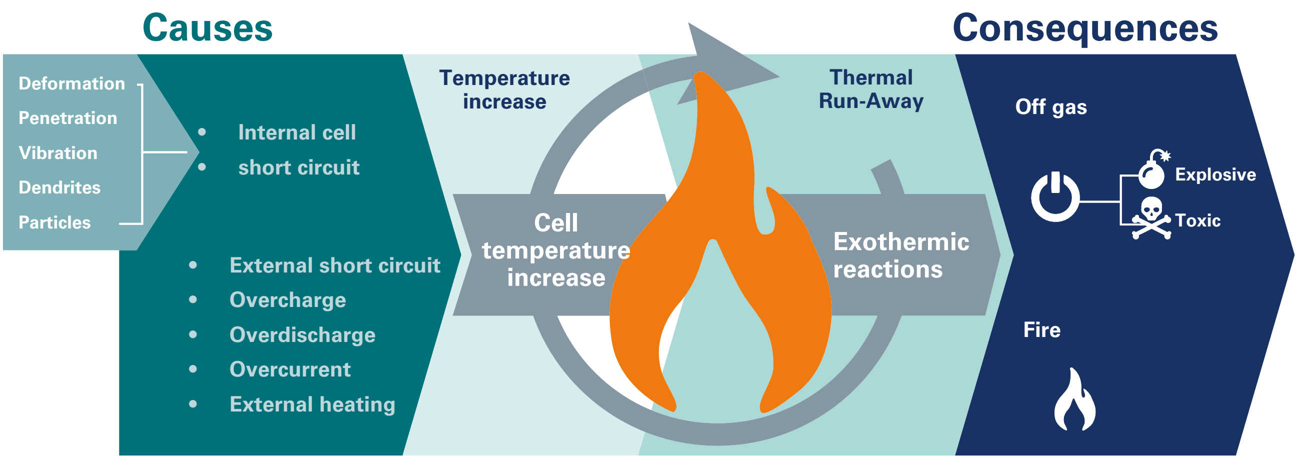
Fire incidents from thermal runaways mostly occur after a crash but can also be caused by unnoticed damage to the cell due to overcharging or battery abuse, which may be mechanical, electrical or thermal.[40] Moreover, battery fires are noted for their difficulty to extinguish and can blaze up again after being extinguished, which is why constant monitoring is required. Thermal runaway can also be caused by the release of gases from a damaged battery, while other hazards may result from the aftermath of a thermal runaway fire. Campbell et al.[41] (2022) noted that thermal runaways are usually preceded by gas emissions from the damaged battery cell.

**HAZARDS ASSOCIATED WITH THE USE OF BATTERIES ON BOARD SHIPS**

- **Thermal runaway**
- **Installation**
  Handling (mechanical abuse)
  Electrical connection
- **Operation**
  Over current
  External short
  Over/ under voltage
  Over temperature
  Condenzation
- **Component failures**
  Temperature sensing
  Voltage sensing
  Communications
  Cell internal short
- **Environment**
  External heat/ Fire

Source: Foresea

FIGURE 5.3.5 Causes and consequences of a thermal runaway in a battery system




Source: DNV GL, 2021[42]

The aftermath of lithium-ion battery fires is as hazardous to OSH as the fire itself. The release of toxic gases leading to explosions has been noted in the literature. This was the case in 2019 with the passenger ferry Ytterøyningen in which a fire was discovered in the battery room. The ferry was saved by a firefighting squad and propelled by its own machinery to the harbour where it berthed and safely evacuated its passengers and crew. However, an explosion broke out in the battery room the following day, suspected to result from the accumulation of explosive gases preceding the battery fire incident. The recommendation is that shipowners should carry out risk assessments to establish the hazards related to the potential build-up of explosive gases during sudden incidents related to the battery system on board vessels. This recommendation is inscribed in the ISM Code.[43]

## 5.2 TECHNOSTRESS

The OSH of seafarers includes dealing with stress, which can be caused by interacting with new technologies, a concept known as technostress.[44,a] It has been observed that technology increases workload[45] and that the usefulness and ease of use of a technology are the two main motivational factors on how and when to use the technology.[46] The uncertainty as to how a new technology will work as well as the safety of its use may be stress factors for potential users. With new technologies, such as battery-powered vessels, seafarers are uncertain about the level of safety as well as the future impact of the technology. Moreover, taking excessive care with batteries during regular replacement and carriage to avoid mechanical damage leading to incidents, such as thermal runaway, may in itself be stressful. In the following section, seafarers working on board M/S Aurora of Helsingborg, a Swedish-flagged ferry, express their feelings about how the transition from working on a conventional ship to a battery-powered one could initially be stressful.

| TYPES OF TECHNOSTRESS |
| --- |
| **Techno-overload:** pressure to work more due to technology and from excessive information |
| **Techno-invasion:** the inability to escape work |
| **Techno-complexity:** time lost to efforts to understand technology |
| **Techno-insecurity:** when your job or status is threatened |
| **Techno-uncertainty:** inconvenience due to changes and computer bugs |

(Dunaetz, D. R. (2022))[47]

[a] For a specific example on technostress related to the maritime sector, please see our case study from the same series of the current report on Technostress titled: Technostress onboard ships: the Danish paradigm.

# 6 OSH REGULATION REGARDING BATTERY USE AT SEA

Ships of all kinds are required to comply with OSH regulations and standards. The existence of laws to protect the OSH of seafarers is an important aspect to be considered by flag States, as is the central role seafarers play in the daily operation of the ship, especially regarding the Just Transition to the use of alternative and more environmentally-friendly power sources in the shipping industry. Regulatory requirements at the global, regional and national levels are discussed in the subsequent paragraphs.

## 6.1 INTERNATIONAL OSH REGULATION REGARDING BATTERY USE AT SEA

The international OSH regulations, which to some extent are related to the use of battery power on ships, mainly reflect IMO instruments, classification society guidelines and the Maritime Labour Convention (MLC 2006). The first two instruments (IMO and classification societies) are primarily related to safety matters, especially regarding hazardous thermal runaway, fire and dangerous gases.

### 6.1.1 MARITIME LABOUR CONVENTION (MLC 2006)

**THE ILO HAS NOT DEVELOPED ANY SPECIFIC LEGAL INSTRUMENT REGARDING THE OHS OF SEAFARERS IN CONTEXT WITH THE USE OF BATTERY POWER.**

The MLC is a comprehensive international labour convention adopted by the ILO's International Labour Conference in February 2006 in Geneva, Switzerland in accordance with article 19 of the ILO Constitution. The MLC sets out seafarers' rights to decent working and living conditions, creating conditions that ensure fair competition for shipowners. It is intended to be globally applicable, easily understandable, readily updatable and uniformly applied and enforced. The MLC 2006 was developed as an international legal instrument reflecting the "fourth pillar" of the international maritime regulatory regime for quality shipping, supplementing the three major IMO Conventions, notably, the International Convention for the Safety of Life at Sea, 1974, as amended (SOLAS 74), the International Convention on Standards of Training, Certification and Watchkeeping, 1978, as amended (STCW 78), and the International Convention for the Prevention of Pollution from Ships, 73/78 (MARPOL 73/78).[48]

Despite the MLC 2006 covering general requirements regarding the protection of seafarers with respect to health protection, medical care, welfare and social security, the convention does not include any specifics regarding the use of alternative fuels or battery power.

However, general specifics that might be applied to the use of batteries, even if they are not directly related, can be found in its Regulation 4.3. This Regulation requires member States to adopt regulations, laws and other relevant measures in accordance with international instruments to protect seafarers on ships flying their flags with respect to OSH. In addition, Standard A4.3 of the MLC 2006 emphasizes the importance of Personal Protective Equipment (PPE) on board for the prevention of occupational accidents. However, it also emphasizes that prevention should take precedence over PPE for seafarers and that PPE should be used as a sole measure when all other options have been exhausted.

The guidelines for implementing the OSH provisions of the MLC 2006, adopted in October 2014 by a tripartite meeting of experts, including experts from governments, shipowner, and seafarer organizations and their advisers, as well as observers from governments and international organizations, invited each country to adopt laws and policies relating to the implementation of the OSH guidelines. The guidelines set out detailed requirements and guidelines relating to OSH and its application in the maritime sector. They outlined the risks involved on board ships and identified the responsible authorities to ensure decent working conditions for seafarers in accordance with MLC 2006 provisions, providing safety training and instructions for all seafarers.

The competent authority of the flag State is required to adapt the guidelines, taking into account the revision of the MLC, including the relevant national laws or regulations, collective bargaining agreements, and other measures necessary to implement the MLC 2006.

### 6.1.2 IMO INSTRUMENTS

**SPECIFIC REGULATIONS OR GUIDELINES FOR BATTERY POWER FOR PROPULSION HAVE NOT YET BEEN DEVELOPED BY THE IMO.**

The international regulations covering ships powered by batteries are mainly related to three types of ships: ships with international certificates (SOLAS ships), ships with national certificates, and pleasure vessels. SOLAS ships above 500 gross tonnes are cargo ships and passenger ships on international voyages. Ships with national certificates can be of all sizes in national waters, or smaller vessels (<500 gross tonnes) on international voyages.

The regulations related to the safety of batteries for propulsion installed on board ships are mainly found in the SOLAS Convention. Technical details are given in specific Codes and Guidelines, such as the Fire Safety Systems Code and the Fire Test Procedures Code. Nevertheless, as the number of ships using large battery installations for propulsion is relatively small, it is essential to highlight that to date, specific regulations or guidelines for battery storage and facilities have yet to be developed by IMO.[49] Still, all available requirements for electric installations highlighted in different parts of the regulation shall or could be applied to battery installation on board ships.

SOLAS Chapter II-1, Part D (SOLAS II-1/40.2) entitled "Electrical Installations" states that:

"The Administration shall take appropriate steps to ensure uniformity in the implementation and application of the provisions of this part in respect of electrical installations"[b]

Moreover, SOLAS II-1/45 entitled "Precautions against shock, fire and other hazards of electrical origin" set out numerous requirements related to basic precautions against shock, fire, and other hazards of electrical origin. In addition, some paragraphs are more specifically related to batteries (SOLAS II-1/45-9), e.g. 9.1:

"Accumulator batteries shall be suitably housed, and compartments used primarily for their accommodation shall be properly constructed and efficiently ventilated."

In a more specific way, fire safety is covered by SOLAS Chapter II-2. The chapter sets out general requirements that can be applied to battery installations. Regulation 4 on "Probability of ignition" states that "ignition sources shall be restricted." Nevertheless, the regulation does not specify how this should be attained with regard to battery installations.

In summary, Chapter II-2 of SOLAS includes general requirements that could apply to battery installations without giving specific requirements, for example sections 5, 6, 7, 8, 9, and 10. To date however, the safety of batteries is still not included in the IMO instruments and is left to the classification societies.

In addition to SOLAS, the International Safety Management Code developed by the IMO provides requirements for shipowners to ensure the safety of the vessel, its equipment and crew. The ISM Code obliges shipowners to carry out risk assessments based on the recommendations in the Code, identifying all potential shipboard risks, which may include fires, floods and collisions, and establishing procedures to quickly respond to these events. Programmes for drills and training exercises should be established to prepare for and handle emergency situations.

### 6.1.3 CLASSIFICATION SOCIETY RULES

The largest classification societies have developed rules that regulate the use of batteries for propulsion. These rules can be summarised as follows.

#### LLOYDS REGISTER OF SHIPPING

In July 2020, Lloyds Register of Shipping (Lloyds) developed specific requirements for lithium-ion battery system installations in their "Rules and Regulations for the Classification of Ships" (Part 6, Chapter 2, Section 12: Batteries). This requirement comprizes rules related to design and construction, location of batteries, installation, thermal management and ventilation, charging facilities, and the recording of batteries for emergency and essential services. Before this updated regulation, Lloyds had only required a generic risk assessment procedure under its guidance note: "Battery installations – Key hazards to consider and Lloyd's Register's approach to approval."

#### DNV GL

DNV GL requirements regarding battery-powered and hybrid ships are stated in DNV Rules for classification: Ships, Part 6, Additional class notations, Chapter 2, Propulsion, power generation and auxiliary systems"[50] and "DNV GL Class programme, Type approval, Li-ion batteries."[51]

DNV GL has also developed two class notations related to the use of batteries on board, which are described in "Part 6, Chapter 2, Section 1, Battery Power" and more specifically

[b] Refers to the recommendations published by the IEC (International Electrotechnical Commission) and publication IEC 60092 – Electrical installations in ships.

in its rules related to classification of ships. The notations are entitled "Battery Power" (propulsion) and "Battery Safety" (over 50 kWh except lead-acid and NiCd batteries).

The additional class notation "Battery Power" is mandatory for ships using batteries as a primary source of power during normal operations or when batteries are used as a supplementary power source for primary and/or additional class notations. The requirement is that when the principal source of propulsion is dependent on batteries only, the primary power source shall comprize at least two independent battery systems located in two separate battery spaces.

The second additional class notation, "Battery Safety", is mandatory for ships using batteries a secondary source of propulsion and has a capacity exceeding 50 kWh. Numerous requirements are listed under this notation. It is required that the battery spaces shall have structural integrity corresponding to the structure of the ship. The fire integrity shall be equivalent to areas classed as other machinery spaces in II-2/9.2.2 with some additional requirements. The site where the batteries are installed shall be monitored and controlled regarding the temperature and explosion risk. Additional requirements are given under this latter point, such as the obligation to have a conventional smoke fire detection system, and a water-based fixed fire-extinguishing system, etc.

More specifically, DNV GL has developed a section about "Lithium-ion Batteries", giving details with all requirements for this type of battery, including battery management system, battery alarms, safety functions, materials, ingress protection, safety description, and testing. The section about testing covers the battery's properties and the battery management systems.

**Bureau Veritas**

An additional class notation has been developed by Bureau Veritas (BV), specifically for ships using batteries for propulsion and/or electric power supply purposes during the ship's operation (Steel ships Pt E, Chapter 10, Section 21). This notation is mandatory in the case where the ship only relies on batteries for propulsion and/or its main source for electrical power supply.

Regarding lithium-ion batteries, the society requests a risk assessment, including battery packs, battery compartment and battery management system (BMS)[c]. The BMS can include the analysis of the following risks:

- Risk of thermal runaway
- Risk of emission of combustion gases
- Risk of internal short-circuit
- Risk of external short-circuit
- Risk of sensor failure (voltage, temperature, gas sensor)
- Risk of high impedance (cell, connectors, etc.)
- Risk of loss of cooling
- Risk of leakage (electrolyte, cooling system)
- Risk of failure of BMS (error on manoeuvring breakers, overloading, overdischarge).
- Risk for external ingress (fire, fluid leakage, etc.).[52]

BV is an advocate of holding technology developers responsible for upholding standards. Tests to achieve safety functions, to ensure proper working of alarms, functions and monitoring systems, etc. should be conducted by the manufacturer based on the national or international standards. Where such regulations are non-existent, the technology developer must include this specification. Tests are also required on board, especially for fire detection, dangerous gas detection, fire extinguishing efficiency and accessibility of battery compartment. The tests also include the positioning of gas detectors as well as the ventilation system.

### 6.1.4 REGIONAL REGULATIONS - EUROPE

Directive 89/391/EEC sets the core minimum standards that enhance the safety and health of workers in the EU. This Directive is particularly concerned with the minimum safety and health requirements for the use of PPE in the workplace.

Directive 92/58/EEC also lays down minimum requirements for providing safety and/or health signage at work. Its importance should be emphasized because it introduces a harmonized approach to safety signs in the workplace. The Directives mentioned above are a welcome development because they help mitigate seafarers' exposure to risks while on board a vessel, especially since risks can be mitigated at the source.

In a more specific way, the European Maritime Safety Agency (EMSA), which aims to offer technical expertise and operational assistance in maritime safety, security, and pollution, works with different stakeholders in relation to issuing technical reports on the safety of ships using battery systems. Numerous stakeholders in Europe are interested in harmonized international regulations on battery safety. EMSA has a role to play in this regard.

[c] Battery Management System (BMS) is the electronic system associated with a battery pack which controls and/or manages in a safe way its electric and thermal state by monitoring its environment, and which permits communication between the battery system and other macro-system controllers. DNV - LG, Technical Reference for Li-ion Battery Explosion Risk and Fire Suppression, Report No.: 2019-1025, Rev. 4 Document No.: 1144K9G7-12 Date: 2019-11-01

### 6.1.5 THE SWEDISH REGULATIONS ON OSH

**WITH THE INCREASED NUMBER OF CONVENTIONAL SHIPS BEING CONVERTED TO BATTERY-POWERED PROPULSION, SWEDEN HAS DEVELOPED ITS OWN REGULATION.**

The Swedish Transport Agency (STA), as the Swedish designated authority, developed the first version of guidelines for battery and hybrid-powered vessels in 2018: "Transportstyrelsens riktlinjer för batteri- och hybriddrivna fartyg - The Swedish Transport Agency's guidelines for battery and hybrid-powered vessels" (TSG 2018-735).[53] The latest version of the guidelines was issued in 2021.

The guidelines include a list of standards and circulars, including IEC 62619:2017, which specify requirements and tests for the safe operation of secondary lithium-ion cells and batteries used in industrial applications, including stationary applications. The guidelines include a risk analysis that should be conducted before any installation of batteries. The guidelines invite shipowners to take into account the EMSA report on Electrical Energy Storage for ships, the DNV[54] report and DNV's and BV's Classification Rules.

In summary, the guidelines invite shipowners to pay special attention to the following aspects:

- Fire safety, i.e. proper placement of equipment, insulation, monitoring and fire fighting in the form of both cooling and extinguishing;
- Correct design of the electrical installation in accordance with current standards;
- Machine installation design and reliability;
- Work environment, e.g. electrical safety for staff in the form of training;
- Operational reliability of the systems;
- Cyber philosophy, e.g. third party distance impact on the vessel

It could be argued that these requirements could guarantee the safety of seafarers on board the vessel if compliance is fully met.[55]

Based on an interview with the Swedish Transport Agency, most OSH issues were covered by the regulations. However, it was highlighted that issues have been raised more recently, such as the health risks related to ash after a fire accident. Work within this aspect is ongoing and undertaken by the agency together with other research teams.

It is worth noting that Sweden was the first country to develop regulations on the use of battery power for propulsion. The work on developing a national regulatory framework on the use of battery and hybrid power started when the company Foresea decided to convert its ship M/S Aurora of Helsingborg, the subject of our current case study, from a being a traditional vessel to a hybrid-powered vessel. Approvals by authorities were needed, but as mentioned previously, no rules for batteries existed at the time. The IMO Alternative Design Guidelines were employed, with the 1455 Guidelines[56] used for the approval of alternative designs. Foresea assembled a design team consisting of several specialists, and Lloyds Register was the classification society. The company has undertaken an extensive effort to develop its own guidelines. The Danish Maritime Authority and Swedish Transport Agency were engaged in the approval phase.

Moreover, the Swedish Labour Law (SLL) highlights several aspects of employee wellbeing. SLL legislation pertaining to employee wellbeing is summarized in the following paragraphs:

#### PREVENTION OF OCCUPATIONAL RISKS

OSH in Sweden is governed by the Working Environment Act (WEA) of 1977, which refers to the physical health and safety of employees as well as the mental and psychological conditions of the workplace. The Act prescribes the statutory foundations of OSH with the objective of preventing illness and accidents during employment to ensure a safe working environment. The WEA obliges employers to sensitize employees and ensure they acquire adequate knowledge of the working conditions and risks associated with their work. The employer has the responsibility to ensure that only employees with such sufficient knowledge and expertize should be granted access to locations where there is a risk of illness or expose to accidents. Other measures include: the requirement to take adequate safety measures to prevent injuries caused by falls, collapses, fire, explosion, electricity and other comparable factors (S:4); to use substances capable of causing illness or accidents only under conditions that would provide safety (S:6); to obligatorily use PPE in situations where adequate protection against illness or accidents cannot be achieved by other means (S:7); to oblige persons installing technical equipment to take into account the necessary safety features in place and ensure that other requisite safety measures are adhered to (S:11). The WEA made specific reference to circumstances relating to work on board ships. It requires that PPE must be provided by the shipowner in the event where other employers have not assumed this responsibility. Although the responsibility for the health and safety of employees and the conduciveness of their working environment lies in the hands of the employer, the Act assumes that there is a high level of cooperation between both parties to attain a satisfactory working environment. In this respect, workplaces that have 5 or more employees are required to designate a safety representative among the employees to represent them in discussions on matters concerning their working environment and to ensure that the employer fulfils its obligations as stipulated by the

Act. Moreover, the Act obliges workplaces with 50 or more employees to establish a safety committee comprising representatives of the employees and the employer. The AWE does not regulate employees' compensation for injuries. This is regulated by the 1976 Act on Workers' Compensation.

### CHANGE OF DUTIES OR POST

The Swedish Labour Law requires the employment contract to be analysed first before any changes are made to work duties. Moreover, such changes of duties are usually considered as offering a new position of employment. The employer may only alter job specifications for just causes. There is also the issue of primary negotiation rights covered by the Swedish Co-Determination Act (CDA), which is an integral component of Swedish Labour Law. According to the CDA, decisions relating to significant changes to company activities that may affect the working or employment conditions for employees are subject to prior negotiations with the unions to which the employees are affiliated, through a collective agreement.

### CHANGES TO WORKING CONDITIONS

In addition to the above-cited regulation regarding changes to working conditions, the CDA obliges employers bound by collective agreements, or who have employees belonging to a collective organization, to provide on a regular basis to their employees' trade unions, certain kinds of information, such as changes to duties that are regarded as not "significant".

### BOARD REPRESENTATION

With respect to board representation, the obligations and procedures for employees' rights are regulated by the Swedish Act on Board Representation for Employees in Private Employment. The goal of the Act is to offer employees the opportunity to be informed about and influence their company's activities through their representation on the Board of Directors. Contrary to the usual proceedings where board members are elected during shareholder meetings, the Act requires employee board representatives to be elected by an employees' organization. In accordance with provisions of the Act, the employee representatives on the board do not have individual signatory company powers. They can only represent the company as part of the Board of Directors. In fact, the Act does not give the employee representatives any special powers or influence over other board members. To avoid conflict of interest, the employee representatives are furthermore not authorized to participate in board discussions on matters regarding certain issues where the unions have a material interest that might conflict with the interest of the employer, for example those related to collective agreements or industrial actions.

# 7 SWEDISH LOCAL CONTEXT

Battery and hybrid-powered ship propulsion has become increasingly popular with Swedish shipowners over the last few years. Examples of hybrid ships (Figure 5.3.7) are M/S Aurora (Helsingborg-Helsingør), which is the subject of this study on the impact of the use of onboard batteries on the OSH of seafarers, Elvy (within Gothenburg), Tellus (Uddevalla-Lysekil) and Jutlandica (Fredrikshamn-Gothenburg). Other ships in Sweden where propulsion is powered by batteries are identified in Table 5.3.A.

FIGURE 5.3.6 An eco-friendly hybrid propulsion system

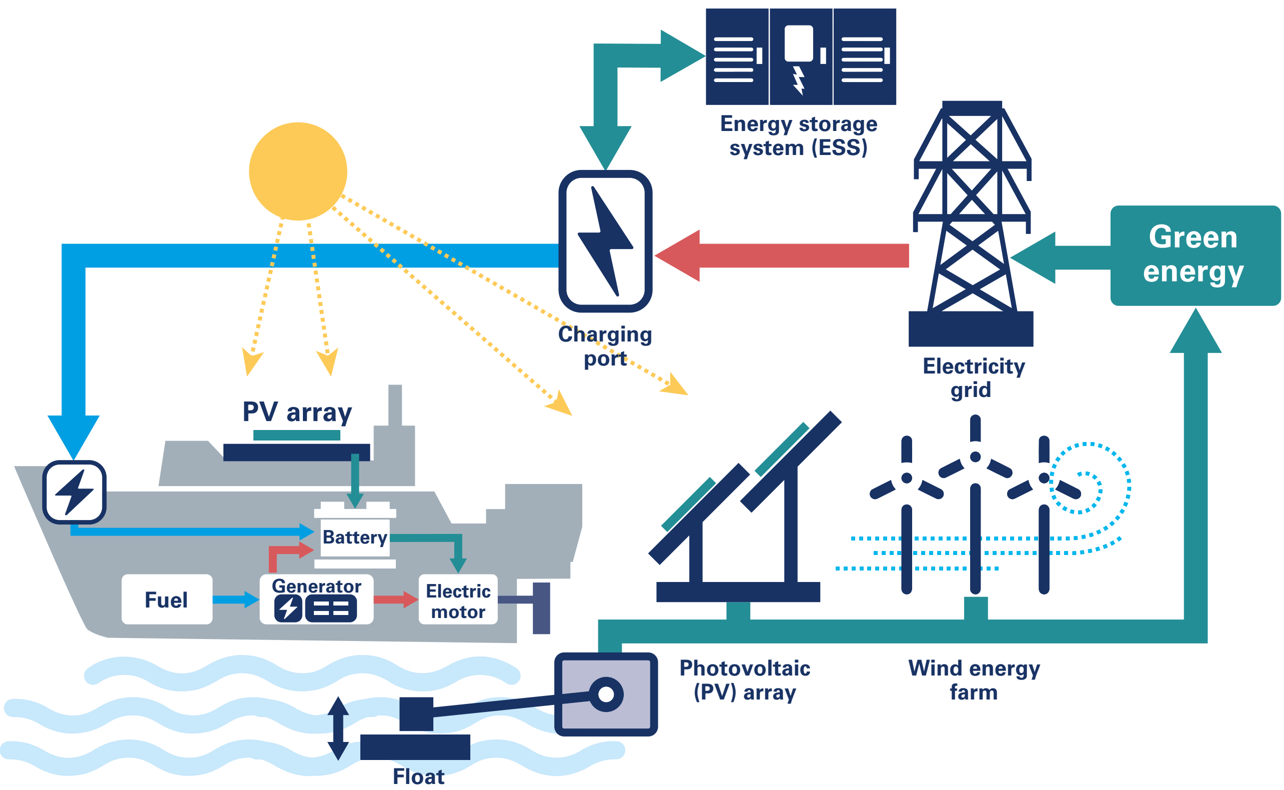



TABLE 5.3.A List of ships in Sweden with battery-powered propulsion

| VESSEL NAME | OPERATOR | ROUTE | TYPE | POWER TYPE | BATTERY SIZE |
|---|---|---|---|---|---|
| **M/S Aurora of Helsingborg** | ForSea | Helsingør-Helsingborg | Ropax | Battery-hybrid | 41600 |
| **Elvy** | Vasttrafik | Stenpiren-Lindholmen (Gothenburg) | Pax | Battery-hybrid | 1008 |
| **Tellus** | Trafikverket Färjerederiet | Finnsbo-Skar (Vastra Gotaland County) | Ropax | Battery-hybrid | 948 |
| **BB green** | Green city ferries | Prototype, Stockholm | Pax | Purely electric | 120 |
| **Movitz** | Echandia/ Green city ferries | Riddarholmen- Solna strand, Stockholm | Pax | Purely electric | 120 |
| **Linje 80** | Rederiaktiebolaget Ballerina | Linje 80 (Sjövägen, Nybroplan-Frihamnen), Stockholm | Pax | Battery-hybrid | 500 |
| **Vilja** | Port of Luleå | Port of Luleå | Tug | Battery-hybrid | 600 |
| **Jutlandica** | Stena Line | Gothenburg- Fredrikshamn | Ropax | Battery-hybrid | 1000 |

## 7.1 M/S AURORA OF HELSINGBORG, A SWEDISH-FLAGGED VESSEL AS A CASE STUDY

The M/S Aurora of Helsingborg, also called M/S Aurora, is a passenger-car ferry built in 1991-1992 in Norway that has been operating between Helsingør (Elsinore), Denmark and Helsingborg, Sweden since April 1992. The project to introduce battery-powered propulsion to this ship was initiated in 2014. The drivers for the initiation of the project were mainly economic, related to high oil prices, and environmental concern, as the operator and the Swedish authorities are very committed to the protection of the environment.

The electrification of M/S Aurora of Helsingborg was finalized in 2018 and approved by the Swedish Transport Agency. The same process was initiated in parallel with its sister ship, M/S Tycho Brahe, which has the same design and purpose as the M/S Aurora and was approved by the Danish Maritime Authority. The ferry operator is currently working on updating M/S Tycho Brahe to feature the largest battery pack ever installed on any ferry in the world.[57]

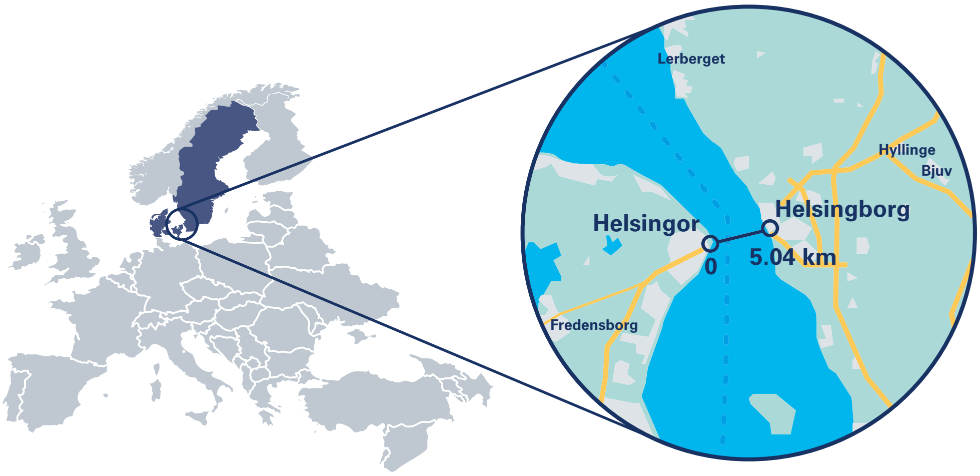
Since the conversion of the 1991-built ferries M/S Aurora and M/S Tycho Brahe from conventional diesel-engine operations to battery power in 2018, the Swedish company has to its own accord reduced its $CO_2$ emission by 37,000 tonnes.[58] Increasing the battery capacity on board M/S Tycho Brahe by 50% will enable Forsea to reduce its emissions even further, resulting in positive impacts on the local environment as well as for passengers. Operating in full electric mode also helps to reduce the emission of $NO_x$ and $SO_x$. Battery operation is furthermore beneficial to the working environment since there is less noise and vibration on board.

FIGURE 5.3.7 M/S Aurora of Helsingborg


Photo taken by: Christopher Kullenberg Rothval[59]

FIGURE 5.3.8 Characteristics of M/S Aurora of Helsingborg

| Region | Map |
|---|---|




| | |
|---|---|
| Length over all | 111.2 m |
| Width | 28 m |
| Average speed | ~15 km/h |
| Passengers | 1200 |
| Vehicles | 240 |
| Gross tonnage | 10 918 tonnes |
| Generators | 4 independent, ~2.5kW each |
| Battety energy | 4 160 kWh |
| Route | Helsingor- Helsingborg |
| Years of construction | 1991 |

Source: Foresea

Large vessels, such as M/S Aurora, can be powered by batteries for their entire route. Upon arrival at the destination (either Helsingborg or Helsingør), the batteries require charging with ultra-fast charging systems and, when needed, the generator kicks in to supply further electricity. Indeed, the electrification of vessels/ferries for green transformation requires both onboard electrical energy storage as well as an energy supply network in the port area. For larger vessels crossing long distances, such as M/S Jutlandia, battery power can be used while manoeuvring in port. The vessel can, for instance, navigate in full electrical mode while manoeuvring from its dock in Gothenburg, Sweden out to open sea. This allows noise and gas emissions within the city to be kept to a minimum.

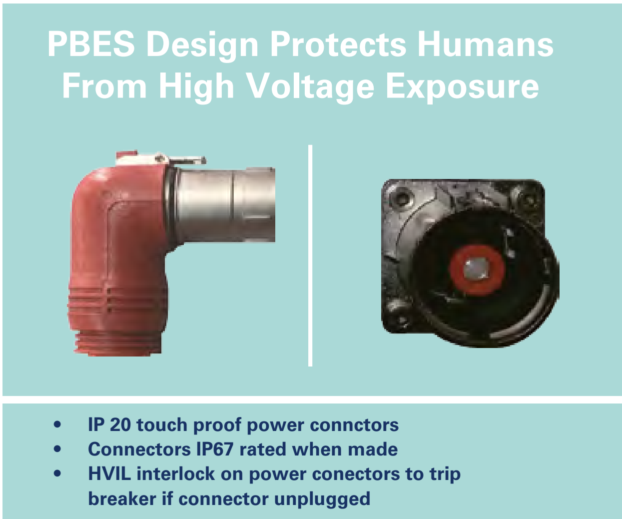
There are 640 batteries on board the M/S Aurora, each weighing 90 kg. The power cables, as seen in the photo (Figure 5.3.9), feature a pilot contact that trips the breaker and prevents arc flash if unplugged, thus preventing accidents in the event where someone falls into the cables during heavy seas.

FIGURE 5.3.9 Electrical storage


Source: Photo taken by the author Khanssa Lagdami - onboard M/S Aurora of Helsingborg, 2022

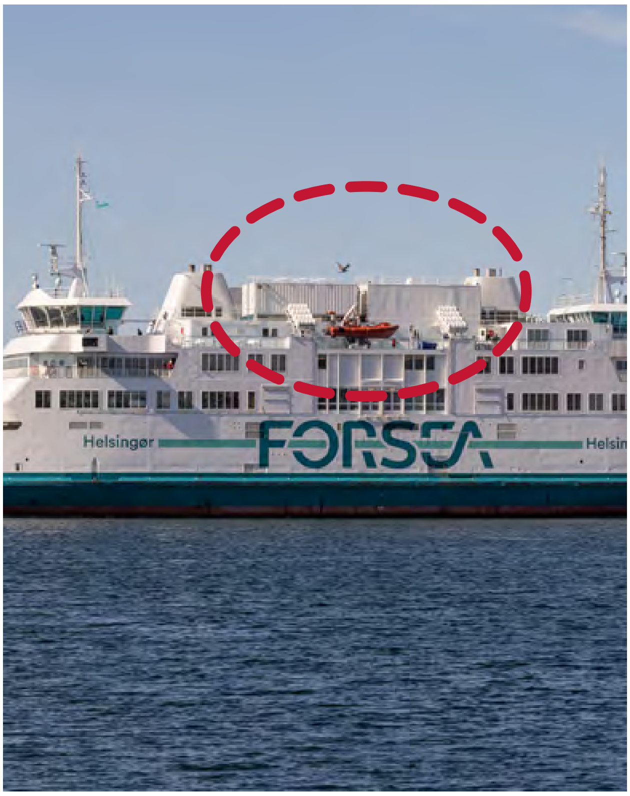
The batteries are located between the funnels on the top of the vessel inside four 32-foot shipping containers (Figure 5.3.11). Once the ship is docked, either in Helsingborg, Sweden or Helsingør, Denmark, the batteries are charged by a fully-automated, laser-controlled robotic arm with a total charge of 10,000 kW to the batteries (Figure 5.3.12). No staff is required during the charging process. According to the manufacturer, the lifetime of the batteries is five years. However, based on recent assessments conducted by Foresea, expected battery life can be up to 5.5 years. Regarding battery replacement, the company has adopted special lifting procedures for hoisting on board, which have been accepted by the flag State of Sweden. Each battery module arrives in complete form from the technology provider. However, although the batteries are hoisted into the vessel by crane, the crew helps position them into the rack.

FIGURE 5.3.10




Source: Foresea company

FIGURE 5.3.11 Location of the batteries




Source: Shutterstock

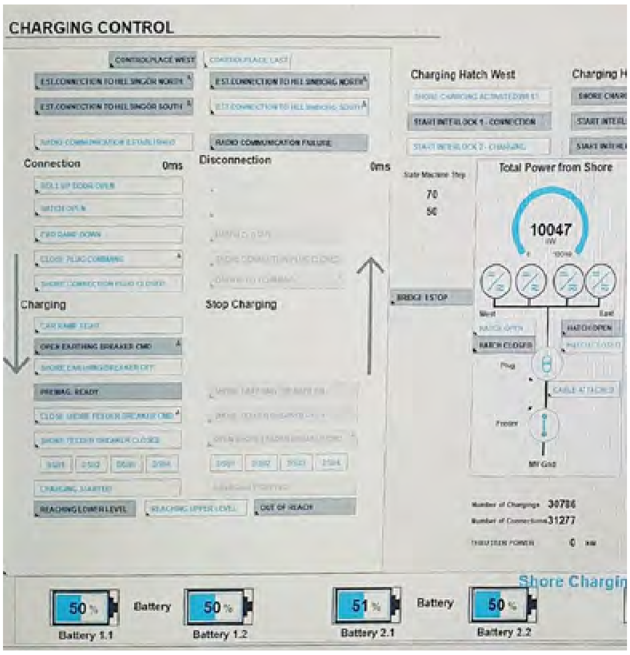
FIGURE 5.3.12 Fully-automated, laser-controlled robotic arm for charging batteries in Helsingborg, Sweden.

Source: Photo taken by the author Khanssa Lagdami - onboard M/S Aurora of Helsingborg, 2022

The ideal State of Charge is between 39% and 66%, corresponding to approx. 1,135 kWh. The batteries can be charged for six to nine minutes at every port stay for a 20-minutes crossing. The average charging time is seven minutes, corresponding to 1,175 kWh (Figure 5.3.13).

The energy storage system was integrated by the technology supplier into the existing infrastructure system through a flexible power distribution system.[60]

FIGURE 5.3.13 A snapshot from the charging vessel battery screen display at the port




Source: Photo taken by the author Khanssa Lagdami - onboard M/S Aurora of Helsingborg, 2022

## 7.2 PRESENTATION OF THE FIELD RESEARCH FINDINGS

The opinions of seafarers on the transition to battery use is very crucial as they are directly involved in the daily operations of the auxiliary machines and the practical use and maintenance of the batteries on board vessels. Ideally, top management should engage seafarers in every step of the conversion process as this will give the seafarers a sense of empowerment and some level of preparedness for what to expect with battery-powered propulsion. Several benefits are brought about by the active participation of seafarers during battery conversion. It ensures mutual understanding between the employers and seafarers and provides ideas on how to achieve the desired result. The results of the interview are presented under the following headings:

### 7.2.1 GENERAL FEELINGS ON THE CONVERSION OF THE SHIP TO BATTERY-POWERED PROPULSION

The general feelings of the crew were assessed from various perspectives. Regarding the use of new technologies, the interviewees confirmed that being sceptical of new technologies is a normal reaction in seafaring. Indeed, initially the crew was sceptical when they heard about the plans for conversion.

However, with the observed advantages, such as the cleanliness of the job when using battery power compared to diesel engines, including no oil leakages, less maintenance and less vibration, coupled with adequate training, the scepticism died down. Moreover, sufficient safety training and collaboration with expert colleagues increased their confidence in working with batteries.

Moreover, there has been no major incident so far, which is why the feelings of the crew regarding the use of batteries are positive. Another interviewee reported that his initial scepticism was not due to safety concerns but rather linked to his disbelief in the workability of a battery system. He said: "Before we had doubts, I was 24, I was actually quite sceptical before we got it up and running, you know, but that wasn't due to safety hazards, it was due to the fact that I didn't think that the system would work."

One interviewee reported initially being scared when he heard about the new technology, but as further information was provided from various sources, and the more involved he became in the early stages of the decision-making process, his level of confidence grew. He said:

"Of course, we were all a little bit scared. But as we grew more educated, we got a lot of information from the suppliers and together we took decisions, and I think it's really important that the people involved in the project or the people that should handle it, need to be a part of it already at the design stage to convince everybody else that they see it as safe or easy (...) So, I think it's really important that the crew is part of what you are designing from the start."

He further iterated the necessity of receiving the right kind of training in the use of the technology and becoming part of the project right from the start so to reduce stress levels. The engineer said:

"It's important that you're a part of the project already in the startup stage. So, everybody can get the stress off. You shouldn't go into this kind of project with stress when you start to handle the equipment on board. Because that might be a reason you make a mistake, so that's really important."

Therefore, to avoid stress among crew members "It is important that they are well-aware of the equipment they are supposed to handle."

The preferences among interviewees were varied. The positive case for battery power was made by an interviewee, who believes this technology is ideal for their ship due to its route being short and because the power requirement is reasonable, which is why the ship can be adequately charged every time it berths at port. So according to him, a battery-powered vessel is ideal, provided that battery charging infrastructure is available in the port. Moreover, while some interviewees prefer battery-powered vessels, another interviewee stated that, as an "old school" seafarer, he prefers conventional vessels due to their familiar layout and that he was furthermore unfamiliar with high-powered batteries.

Some interviewees voiced the opinion that battery-powered propulsion is a good system and that there is no need to worry about battery use because there are experts available at any given time with adequate knowledge. In any case, the vessels can easily switch back to the conventional system if a potential risk is observed. One interviewee, who was positive towards battery systems, maintained that the issue is complicated and that not everyone is trained in the use of battery power. More in-depth knowledge is therefore required. Another interviewee noted that the change in work routines and duties among seafarers only affected those who work directly with this technology. Those who do not work regularly with the batteries have not experienced any change in routine.

Regarding the crew's feelings about their safety, they all confirmed feeling safe. However, some added that although they feel safe, they are also conscious that in the event of exposure, it could result in a disaster. Most interviewees worry more about the electric cars carried by the ship (the cargo) rather than the ship's own batteries, because incidents such as the Tesla fire incident (cited by most of them) show that when a fire breaks out on the car deck, it is uncontrollable. Another interviewee stated that he generally feels safe but feels uneasy when thinking about what could happen if a fire broke out. The interviewee believes that:

"No one can predict what will happen in the future, therefore battery safety is not something the crew should be worried sick about."

To him, the most important thing is to follow the safety instructions and, so far, he feels safe. It can therefore be inferred that most interviewees feel safe on board a battery-powered ship and their degree of assurance is determined by various aspects, such as their level of confidence in working with batteries, the level of safety training they receive, their personal courage, and their acceptance of the fact that the ship is their duty station and they therefore need to take precautions.

The interviewees also noted that there are periods where it is unsafe to work with batteries, such as when there is bad weather or a storm. They are unable to remove the battery modules during such circumstances because there is a risk of dropping them and, if that happens, there may be mechanical damage to the battery that can lead to hazards, such as thermal runaway. It can be inferred that the fact that the crew is so conscious about avoiding mechanical damage to the batteries could, in itself, be a stress factor. However, the crew confirmed that there have been no battery incidents so far and therefore no periods during which their work has been interrupted due to an incident caused by batteries.

The interviewees also reported that battery use has added welcome change to daily operations, including no longer being exposed to the risks of orange chemicals, exhaust leakages, system overhauls and overheated engines. Battery power also requires less maintenance and causes fewer vibrations and less noise. Nonetheless, an interviewee complained about cold temperatures during winter. The heat from the regular operation of a diesel engine is helpful during winter in keeping the crew warm, although uncomfortable during summer. Since battery systems do not emit heat during regular operation, fan heaters have now been introduced on board during winter. One interviewee believes that battery power is a good system and "more or less the same" as the conventional system. However, he also complained that "it's a little bit more equipment with a little bit more cooling systems and a little bit more monitoring." All interviewees agreed that "this is a cleaner job for us, actually," and they "think it's better quality." Finally, the interviewees also indicated that the biggest change to their work brought about by the shift to battery power is having to undergo regular training on handling high-voltage installations and the risk of thermal runaway on board. However, they do not perceive the training as a stress factor but rather as a means to capacitate and prepare them to handle battery-related incidents, to enhance their skills in the use of batteries and the technical issues related to their use, and to prepare them for any unpredicted eventualities.

### 7.2.2 PARTICIPATION OF WORKERS

The case study confirms that all interviewees had been informed about the conversion to battery power. Some participated in discussions on the conversion but not at a managerial level. For instance, when asked if he had participated in the meetings about the shift to battery power, one interviewee stated:

"Yeah, involved in part of the good discussions, too . But more on basic knowledge. I wasn't sitting on battery meetings, you know, when they did the big planning. But however, with suggestions and all kinds of stuff, we've been involved by the company."

Some interviewees have attended planning meetings. One interviewee reported that "he has been telling us every step in everything, so that's good. Because they want us to know. Yeah. All parties know what's happening." Another said: "yeah, we're all part of it, so we know what's happening." Some mentioned being involved right from the design stage and having been part of a large team that comprized the Class, naval architects, flag State authorities, crew, the suppliers of the equipment and their subcontractors, manufacturers of the batteries, and other engineers. In the words of one interviewee:

"We were a big design group working together for almost two and a half years. And there were participants from the Class. We have Lloyds, our ship is registered in Lloyds. So, we had representatives from different departments from Lloyds. We had our naval architect, who was always from OSK ShipTech in Copenhagen. They are naval architects and specialists in the building of new ships and conversion of old ships. It was the flag State authorities in Sweden and the DMA in Denmark. Us from the crew were a part of it because we had the knowledge of the space and all of that. Yeah, and of course, their supplier of their equipment was part of it. So, from our point of view, it was BB Marine in Finland and also their sub-contractors, plan B energy storage from Vancouver, Canada. They were the manufacturer of the batteries. And we also had the engineers from Ammoland who did the design and the steel conversions and fire philosophy in the handling of batteries."

He further iterated that "there were some of the crew in the design team all the time. And we had to work in close cooperation to follow the Class flag State rules in the countries of Denmark and Sweden, and also Lloyds, to respect the safety issues in all matters."

This indicates that although not all crew members were involved in discussions, they had representatives, especially senior engineer colleagues, who could pass on information to the others.

### 7.2.3 THE INCREASE OF WORKLOAD

In response to the question whether the introduction of battery power on board the vessel had resulted in an increase in workload for the seafarers, such as more data analysis, the shipping company management answered:

"All the engineers have been educated in high voltage and all engine ranks have gone through high-voltage safety courses, firefighting of lithium-ion batteries and first aid courses for electrical accidents. As the ship can run in both battery mode and hybrid mode, the diesel electric system still needs maintenance. In general, the conversion has increased the workload of the engine crew in maintaining and collecting data from both systems. This has been solved by adding three more full-time employees (engineers) to cope with the workload situation."

Some of the interviewees mentioned helping out with the change of batteries, which may indicate that their job description has been changed slightly. No further information has been collected regarding work contracts and their descriptions. It is nevertheless clear that during the entire process of the conversion to a battery power, more and more specialists became involved. The company has invested greatly in training.

### 7.2.4 RISK ASSESSMENT

According to ILO, an important objective of OSH measures is to prevent occupational accidents, injuries and diseases by managing occupational hazards and risks. The identification and assessment of risks enables the identification of the aspects of seafarers' working environment and property that are vulnerable to hazards, enabling the development and implementation of appropriate preventive and protective measures. The risk assessment process involves identifying the hazards and determining who is susceptible to which type of harm; evaluating the risk; identifying and deciding on the safety and health risk control measures; recording who is responsible for implementing which control measure and when; recording the findings; monitoring and reviewing the risk assessment and updating when necessary. The effectiveness of a risk assessment lies in the reliability of the data gathered and analysed as well as on the statistics. ILO recommends the use of a risk methodology, such as a risk matrix, to assess the identified risks based on the probability of occurrence and the gravity of the repercussions. Moreover, the assessments should be reviewed whenever there is a change in the functioning of the ship in terms of personnel, processes, work methods or shipowner, or after investigations of accidents and incidents and analysis of hazardous circumstances. This ensures that improvements are made and the occurrence of similar situations is prevented.

The Swedish perspective regarding risk assessments follows the same line of inquiry. According to the Swedish Work Environment Authority,[61] risk assessments should be carried out after a thorough and continual investigation to identify deficiencies in the organizational and social work environment. Information can be gathered through discussions with employees, planned meetings, occasions and workplace encounters. Moreover, anonymous employee surveys have proven to be effective in revealing possible deficiencies in the organizational and social work environment. The results of such surveys are important starting points for risk assessments as they reveal the extent of the risk and the vulnerable parties. With the aim of assessing work-related vulnerabilities and consequences, such as ill health, risk assessments consider such factors as risk of incidents and the duration and frequency of occurrence, together with such factors as cooperation, social support and opportunities for recovery.

The case study shows that all crew members are aware of the location of the onboard batteries on deck seven and of the fact that something could potentially go wrong. This means they are aware that using batteries is risky. Some of the inherent risks, according to the interviewees, include high voltage, presence of gases due to battery expansion, and thermal runaway and electric shock. They are furthermore aware that physical exposure factors may lead to OSH issues. All crew members stated that the batteries are very heavy and that they are exposed to their weight when occasionally having to move them. However, the shipping company has made provisions for lifting equipment, such as lifts and pulleys, which aid in moving the batteries. No crew member has therefore until now encountered health issues due to battery weight. The fact that the space of passage between the batteries is very narrow is also significant. This is a design issue, and one interviewee stated that although this has not caused a health issue so far, the designers should consider this aspect with future battery designs.

The presence of heat/ high temperatures should also be considered. This has been addressed by the installation of water cooling systems. According to an interviewee, although these stress factors of physical exposure exist, crew members are not really exposed to them because the manufacturing company (ABB) is in charge of maintenance and the crew simply assists. Moreover, the exposure to heat is less on battery-powered vessels than with conventional vessels because the crew is not that often in contact with the batteries. One interviewee, for example, only checks the batteries twice a day.

The interviewees also stated that although battery incidents are a potential risk then the main risk factor in their experience is human error. One interviewee added:

**"It is always a human factor thing about the cable. Yes, it's like an error."**

They also confirmed that risk had mainly been a factor when they had just started working with batteries.

One interviewee also noted that unforeseen risks may exist due to design issues. He explained a particular instance when such an issue was encountered and how it was handled: "There are 24 cells in each module, and all 23 could expand, except the last one, the 24th. There was no space for that particular battery to expand. So, when it did expand, it caused a deformation of the backside of the battery. And that deformation could be a risk because if you had a thermal runaway of that cell, it might emit explosive gas into the area where the crew was working, and we could have an explosive environment. So that was really dangerous, but we never came to that situation, but it was not predicted by the designers in Canada that this could happen." In this case, the risk was identified and the system was immediately shut down.

The interviewee also stated that design issues with batteries may be due to most batteries being retrofitted on ships. The case is different with ships designed and constructed for battery-powered propulsion. Current battery-powered ships (especially those in the case study) are retrofitted; hence, structural issues are inevitable. He noted:

**"There's an issue when you convert a shape you have, the space you have, you know. If you build the ship from the beginning as a battery ship then you can do this in another way but we had limited space. And we had to reinforce the shape to put the weight here, and we couldn't get the other part, so it was impossible for us to have a bigger space for all the equipment."**

The interviewees recommend including sufficient space in future battery-powered ships. They also stated that some modules become faulty and need to be changed. The circumstances are unpredictable. One interviewee said:

**"We have moved 10% of all the modules that we had from the beginning until today and changed the circuit board... We didn't expect that, of course."** In conclusion, it can be inferred that the crew is aware of the risks and their scope.

### 7.2.5 PREVENTION

Prevention precedes risk assessments and, according to ILO, the assessment of occupational risks is a crucial element in selecting effective preventive and protective measures to plan and organize work and to reduce exposure to hazards. The fostering and promotion of a preventative safety and health culture is a fundamental prerequisite for improving OSH performance in the long term. This requires the use of all available means to increase general awareness, knowledge and understanding of the hazards and risks and how they may be prevented or controlled.

The implementation of preventive measures in organizational and social work environments in the Swedish context necessitates the consideration of several factors, notably, working hours, victimization and workloads. The responsibility for OSH lies in the hands of the employer; hence, the employer is required to assign tasks to employees that do not result in unhealthy workloads or accidents. As such, the quantity of work and the difficulty of the tasks are important aspects to consider. Moreover, the employer is required to ensure that technologies, where they are used, are designed for and adapted to the work being carried out. Also, the identification of the root causes of excessive workloads is vital in order to implement effective measures to improve the situation.

In the case study, interviews with the crew highlighted several preventive/safety measures implemented on board the ship; namely, regulations, prior stress testing of the batteries, information sharing, and watching safety tutorials about risks. Some "better safe than sorry measures" are also observed, such as shutting down the battery system when any slight risk is perceived. Supplier companies are usually selected after a stress test has been performed. In the words of an interviewee: "There are safety regulations around it, and everything is tested very well. And we got very well informed as well about this testing. And we have watched a lot of safety videos with things like thermal runaway, and all these features that are new to the battery industry when you actually use batteries."

The interviewee added that **"We did, of course, a lot of stress tests of the batteries in a laboratory before we choose the supplier because it was very important that it was safety-first when it comes to the battery, and at RISE in Gothenburg we did some stress tests of the batteries, and it was very important for us to choose which supplier we went for at the end of the contract."**

In one particular case, an explosion occurred during the performance of a test, leading to the rejection of the company. The interviewee explained:

"We chose them to do one of our tests with one of the suppliers and actually it went really bad. So, there was an explosion with that battery. The complete wall was damaged inside the test area. So, we didn't choose that supplier. So, we chose another supplier."

Another preventive measure carried out is the measurement of electromagnetic compatibility (EMC). According to the interviewee:

"It's very important to check when you do this. We have a high voltage and a leg of electricity, many power cables. And so also, we did EMC measurements during the startup period to make sure that there's no EMC going through the people working in these area; that's really important."

The manufacturers of the batteries are also required to conduct a test of short runaways. This entails a process of how to prevent runaways from continuing to the next cells. Moreover, to prevent any incidents, the battery is not moved while the ship is on route. It is removed while the ship is berthed in the harbour to prevent any mechanical damage.

Other types of preventive measures implemented include the use of exhaust fans, alarms and gas monitors. The crew maintained that they are well protected with PPE, such as safety shoes and gloves. Moreover, to prevent health issues, such as waist pain during the lifting of the batteries, the company has put in place the use of tools such as carriages, lifts and trolleys. Additionally, the crew said that they rarely lift the batteries, and that the lifting is usually conducted by the manufacturing company's technicians, and they just assist. The company has also implemented a safety management system with many written instructions and specified procedures on how to handle the entire battery system.

The interviewees believe that they have understood the safety and preventive measures and have been well trained by the subcontractors. When asked if he understood all the safety measures regarding the use of batteries, an interviewee replied:

"I think so. We've done a lot together with the subcontractors. We've done a lot of training, we are trained how to handle different situations."

On the effectiveness of preventive measures, the interviewees confirmed that: "the system warns long before it reaches a dangerous temperature," and circuit breakers shut down the system should anything occur. The system is an automatic shutdown system, also known as a smart system, that communicates with itself and shuts down automatically should any faults be detected. "It's quite bullet-proof so to speak," an interviewee said, adding: "there's a lot of safety built into the system… a lot of safety that is in the integrated automation system."

Several interviewees shared the opinion that the effectiveness of preventive measures can only be questioned if something goes wrong.

"No incident has occurred since the shift to battery power." Their conclusion is that since no incidents have occurred, the measures are effective. One interviewee believes that the crew is well-equipped because the company invests greatly in safety training regarding issues related to battery use, especially thermal runaway, and how to handle all the new equipment integrated into the automation system. However, the same interviewee noted that despite attempts to prevent all conceivable safety issues, one cannot predict disaster. He noted that:

"Harrisburg would never happen but it did, so nobody knows for sure because we tried everything during the design stage. We tried to stress test everything and tried to think about every possible thing that can happen. We think we are very safe today."

Regarding the company's safety culture, one interviewee testified to the company being very open, where the crew is free to bring up issues and suggestions without fear. They have "no blame culture." The respect for workers' safety is high. Sometimes issues are reported through the safety committee.

Despite all these preventive, protective and safety measures, the crew still thinks that "there is always room for improvements." They stated that since battery power was first introduced they have learned a lot and have been improving their routines. An interviewee stated:

"Because it's a learning curve every day, actually. We still learn and we have improved the safety routines we have had, and we've seen things during this time. There will still be additional matters going forward. I'm sure we will still discover weaknesses in the system in the future."

### 7.2.6 EMERGENCY PROCEDURES

As an integral part of their safety and health policy within the area of OSH policies and programmes, shipowners are required to develop and implement efficient and effective emergency and accident response action plans (EARPs), which provide adequate information on the procedures, programmes and activities to mitigate risks to human life. Moreover, the staff responsible for the implementation of these plans must be trained and drilled. Activities developed must be described in the EARP and seafarers should familiarize themselves with its content.

The emergency measures identified in the case study by the interviewees included a firefighting SIFT system that involves pulling the batteries out from the outside of the vessel and filling the battery containers with water; firefighting blankets; a water cooling system; aerosol for igniting; boundary tooling; energy programmes; and weekly training. With all these emergency measures available, a crew member said: "I don't worry too many hours about it."

When considering the effectiveness of emergency measures, the interviewee believed that the location of the batteries at deck level is an appropriate emergency measure. They added that it would have been easier if the system had been designed with a spring to pull out the battery containers during an eventuality, so they could be filled with water. The crew members equate the fire hazard of the batteries to that of a burning electric car and noted that, based on the Tesla case they had seen on YouTube, such a fire can be so severe that it cannot be extinguished, but can only be contained and prevented from engulfing other vehicles. However, they also noted that they believe the adopted emergency measures are effective since nothing has gone wrong so far, but there is always room for improvement.

### 7.2.7 ACCIDENT REPORTING

It is important to establish channels through which employees can notify the employer about high demands and inadequate resources. Leadership that promotes regular dialogue with employees will create an environment in which the signs and signals of unhealthy workloads can be identified and imbalances corrected, and accidents and incidents can be reported freely for necessary action.

Regarding accident reporting, interviewees in the case story noted that a reporting system is available where complaints regarding incidents or potential incidents can be reported. In most cases this is done through the safety committee. The interviewee explained:

"We have a safety committee on board where all different departments from the ship are always represented during the committee meetings where you can bring up whatever issues."

Moreover, safety meetings are held every morning and during such meetings any new safety measures are communicated to the crew. There are also safety manuals available which could be amended if required. One interviewee believes that although a reporting system exists, there is always room for improvement.

### 7.2.8 TRAINING

According to the interviewees in the case story, their crew members have been properly trained. The training modes include courses on how to handle high voltage and prevent thermal runaway, training in firefighting and electrical safety, small in-house workshops, memos and updates communicated every morning during meetings, new safety features, rules, and service bulletins. In the words of one interviewee:

"First aid for electrical accidents everybody's been trained in, also everybody has been trained in all the safety rules concerning high voltage."

Another interviewee confirmed, saying: "We've gone through five different courses, depending on which rank you have, on how to be trained, and you use high voltage and batteries with high power just to avoid not having an action that causes an accident."

Training courses on electrical safety have been conducted and the crew has been instructed in the distance to be kept from the area of concern because an electric spark can travel a long distance, depending on the voltage. An interviewee said:

"They trained us on how to avoid thermal runaway and how to act if there is a thermal runaway."

The training also includes how to connect fire hoses and use the sprinkler inside the container, and how to stop the fire pump and flush the container with water. Part of the training involves how to activate the emergency stop button and alert the control room. The interviewees expressed a high level of satisfaction with the training. The presence of written instructions in the safety management system was noted. The crew also stated that a lot of written instructions are available on how to handle the battery system and its various parts, so "I will say we are very skilled at handling our equipment."

An interviewee reported only having had training a couple of times and that the crew is mostly learning from practice. He stated:

"We're actually learning a little bit all the time, and the second engineers are always training the others because they are the experts."

However, when asked about their opinion on the sufficiency of this training, an interviewee said: "But you can never learn enough, you know, but I mean, as of now, we reached a point where we were just advancing all the time... it's an ongoing process."

Similarly, another interviewee stated that although they have good training, it is never enough. There is a need for constant learning because some aspects of the training are forgotten with time. Another interviewee believes that the current training is enough but no one knows for sure since they are at the forefront of this new technology. The interviewee stated that for now, everything has been calculated theoretically by the designers but unpredicted issues may still be identified deeper into the project and require additional education or training.

"But at this point, I think we have tried to focus on all the risks by identifying the different risks. I would say at this point that we are safe, and I think the crew feels safe too," the interviewee said.

Another interviewee believes that he has no need for further training because the system is somehow automatic. Another interviewee expressed a need for more electrical knowledge. "If I could go and actually take my Bachelor of Science degree again, I would wish to have more electrical knowledge in school," the interviewee said.

Finally, a senior engineer advized that although the company has done a lot to reduce risks and ensure the safety of the crew, they are still required to exercize due diligence when carrying out their duties:

"But like we said before, we have risk assessments, how to handle the batteries, and we follow them very hard and so there's a need for discipline when you're working with this kind of equipment. You need to be focused, and you need to be skilled, and you need to be educated. It's really important for future projects that a ship's crew is involved from the beginning, like we said before, and that they are skilled and educated in handling all these risks. So, they are aware of that because then they would be more careful and not handle things the way they shouldn't," he concluded.

# 8 DISCUSSION AND LESSONS LEARNED

Scepticism when faced with new technology is a common phenomenon. The seafarers were initially sceptical about the introduction of the new battery technology on their vessel and about being required to work with it on a daily basis. This scepticism may be due to the uncertainty that surrounds the use of the technology and the concerns of seafarers regarding OSH risks. Another reason for their scepticism was the lack of knowledge they had about battery power and the insecurity the technology posed in relation to the nature of their work. The seafarers stated that their scepticism abated after receiving training and when realising that their job would become cleaner as the result of eliminating or reducing OSH threats, such as exposure to oil leakages and yellow chemicals, vibrations, maintenance work and fatigue.

Vibrations, which are oscillating movements transmitted through solid materials, are an imminent cause of health issues for seafarers and may affect the whole body due to the movement of the ship or when working near vibrating machinery. Vibrations may cause short-term health effects, such as motion sickness, body instability and fatigue, and long-term health effects, such as vascular, neurological and/or musculoskeletal damage; poor blood circulation and circulatory pain; tingling, numbness or loss of dexterity; carpal tunnel syndrome; whole body vibration; low back pain, sciatic pain or degenerative changes in the spinal column.[62]

Furthermore, fatigue is also reduced due to less frequent maintenance work. Fatigue, which has no universally accepted definition, is recognized by many as being the degradation of human performance. IMO[63] defines fatigue as "a reduction in physical and/or mental capability as the result of physical, mental or emotional exertion, which may impair nearly all physical abilities, including strength, speed, reaction time, coordination, decision-making or balance". Some common causes of seafarers' fatigue are sleep deprivation, poor quality of rest, stress and excessive workload. In the case study, the seafarers confirmed that the number of hours spent on the maintenance of diesel engines is far greater than those spent on batteries, which seems to be a positive aspect of battery use that it reduces the risk of worker fatigue.

Scepticism is also reduced by adequate training. The seafarers stated that the training they receive in the management of electricity and onboard high voltage builds their confidence and has changed their attitude to battery power. This shows that adequate knowledge and education in the handling of new technologies could reduce OSH issues on board ships. One seafarer's reasoning for being sceptical was not due to safety concerns. He was young (24 years old) and inexperienced. Initially, he did not believe battery-powered technology would work, a notion linked to his knowledge about how batteries normally function as a source of energy. Most seafarers worked for the company before battery-powered propulsion was introduced on the ship. The study demonstrates they were informed about the shift beforehand and some even took part in early meetings at the design stage. This indicates that information sharing, knowledge and education about new technologies are important steps when changing the mindset of people faced with the dilemmas of new technologies. Education is one of the most important aspects of successfully introducing new technologies to seafarers.

There is also the aspect of collaboration between workers. The seafarers stated that since starting to work with batteries they are no longer worried due to having expert colleagues with sound knowledge. In addition, before starting to work with batteries, they had studied the briefs and safety management system instruction manual. Their level of anxiety decreased as they gained confidence by following safety instructions and learning how to avoid the negative impacts of the technology on OSH.

Their preferences for working on either battery-powered or conventional ships varied individually among seafarers and the study indicates that the preference to work on conventional ships was due to a number of factors, including lack of familiarity with the management of high electricity on a battery-powered ship; the crew member's regular duty being unrelated to batteries; and a preference for a conventional ship's layout and a high level of acquaintance such technology. This general lack of familiarity with battery power among the crew is the result of electricity and high-voltage training in the company being limited to those working directly with batteries. Those who preferred working on battery-powered vessels were unconcerned with batteries since they considered themselves well-trained in handling eventualities. According to some seafarers, their main concern is with the electrical cars on the car decks of the ship. They have watched videos of how electrical car fire incidents occur and most of them described such fires as uncontrollable. A lack of prior knowledge of the technical conditions of the cars before being loaded on board made them more worried about the batteries of the cars than those of the ship that are regularly monitored. Moreover, the most common risk with the use of lithium-ion batteries is thermal runaway, which mostly occurs after the battery has been subjected to some form of stress (possibly mechanical). This explains why, according to the crew, battery removal is not carried out when the ship is on route but when at berth. Precautions must be taken not to drop the batteries or to cause any damage to the battery that could lead to thermal runaway. This is also reflected in the crew's feelings about safety.

All crew members feel safe, although they are aware of the magnitude of a potential battery-related disaster, which sometimes leads to an uneasy feeling. However, the crew feels safe due to the safety culture of the company where a safety management system is in place with written instructions; preventive measures, such as firefighters; protective measures, such as gloves, goggles and safety shoes; morning meetings and in-house training. Although PPE is a good protective measure, the ILO noted that the use of PPE depends on human response and should only be used as a sole preventive measure when all other options have been exhausted. PPE is considered a last resort when exposure to risks cannot be prevented, minimized or eliminated.[d] According to the interviewees, whether the preventive measures are effective or not can only be judged by whether an eventuality has taken place. The crew noted that since the use of batteries had been introduced, no incident had occurred. Therefore, they assume the preventive measures to be effective. Additionally, in investigating the causes of incidents, the interviewees noted that an incident may indeed not result from technical issues because the system is a smart system that warns users long before things becomes dangerous. Instead, they see potential incidents as resulting from human error. This finding is consistent with an IMO study that found that 80% of accidents on board cargo ships are caused by the human factor.[64] Some crew members not working directly with the batteries claimed not to be familiar with electricity and high voltage. This shows that crew familiarity with electricity and high voltage is limited to those working directly with batteries.

As a result of the above observations, the following recommendations have been developed. These recommendations may also prove applicable to the adoption of technologies other than batteries:

| | |
|---|---|
| 1 | The inclusion of seafarers in the discussions regarding the shift to battery power is very important. Since the technology has already been implemented, any redesign or modification of the current design should include input from its current users and those who operate the batteries on a daily basis. |
| 2 | Ensure that workers (ratings) have a "real and effective" say in the development and implementation of technology. Governments should develop regulations to clearly define their role in the entire process. |
| 3 | Increased social dialogue would be important. Shipping companies should work more with social partners and other stakeholders, providing explanations to the workers about alternative fuels and their potential use. The sharing of information is a very important factor that relies on collaboration between different actors in the sector. |
| 4 | With respect to the use of battery power for propulsion, all crew members on board should undergo electricity and high-voltage training regardless of whether they are working with batteries or not. |
| 5 | For other alternative power sources, more specific training would be needed depending on the choice of technology. The focus should be on adaptive learning and how the training can be useful in real working life. |
| 6 | ILO and IMO should urgently develop regulations on the use of some specific technologies already present in the market. |
| 7 | Changes in the employment terms may occur (since some seafarers assist with the change of batteries, as shown in the case study). Regulation should be clear and in place with respect to the adoption of new technologies. |

[d] MLC (2006), Guideline B4.3.1, para. 3. This hierarchy in the implementation of preventive measures is at the core of OSH principles and is included in many regulations and guidelines, among them the ILO Guidelines on occupational safety and health management systems, ILO–OSH 2001. Another example is the European Union's Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work, available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:3989L0391

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COUNTRY REPORT – PANAMA

# SHIPBOARD INTERNET USE: AN INVESTIGATION INTO ITS INFLUENCE ON THE OSH OF SEAFARERS

## CASE OF PANAMANIAN-FLAGGED SHIPS

5.4

(Photo credit: SAN KO OO, reprinted with kind permission of

# 1 EXECUTIVE SUMMARY

Seafaring is a challenging profession. From tight and extended work shifts to contracts that usually involve seafarers being away from their homes for months. Seafarers must deal with stressful situations while sailing in the middle of the sea with nowhere else to go. These issues lead to problems such as feelings of isolation, depression, lack of sleep, fatigue, family issues, and labour conflicts among seafarers.

Under the Maritime Labour Convention, seafarers were granted a tier of rights regarding minimum standards for working conditions.

One of the rights granted to seafarers in the MLC 2006 is decent accommodation and recreational facilities on board. This includes "reasonable access to ship-to-shore telephone communications, and email and Internet facilities," as stated in Guideline B3.1.11, para. j. On 13 May 2022, the MLC Special Tripartite Committee (STC) meeting concluded with an agreement on several changes, including a commitment to better social connectivity for seafarers.

Nevertheless, some national laws do not clearly describe the right of seafarers to Internet access, leaving gaps for the stakeholders (shipowners, seafarers, and the flag State) to interpret the guidance in a way that best reflects their interest.

As part of a series of the Future of Work 2040 country reports studying the impacts of technologies on the Occupational Safety and Health (OSH) of seafarers, this report investigates the effects of Internet use on the OSH of seafarers. The analysis sheds light on the two faces of the coin: the use of the Internet on board and the current limitations of its availability. This study focuses on seafarers working on Panamanian-flagged ships and therefore does not offer a complete picture of the international maritime industry. The study only provides a snapshot of how the Internet may influence the OSH of seafarers on board, both in the case where there is ready access to the Internet and where there is a lack of Internet connection. Despite numerous attempts to encourage participation in the survey, only 239 seafarers responded, with three accepting to have in-depth interviews. The survey was open for respondents between 15 April and 30 August 2022.

The study has resulted in the following recommendations:

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| 1 | Like all other workers, seafarers should be provided with unlimited access to high-quality Internet. The study indicates that poor Internet quality, or a lack of shipboard Internet, risks resulting in mental health issues among seafarers. Advocating for high-quality Internet on ships among shipowners and flag States could potentially help minimize stress and maximize social relations among seafarers on board. |
| 2 | Shipowners should provide facilities and an environment that encourage seafarers to engage in more social activities with their onboard co-workers. They should actively solicit ideas for social activities from seafarers. |
| 3 | An awareness campaign should reach out to seafarers with advice on the potentially harmful side effects of the excessive use of onboard Internet (like with any other workplace). Seafarers should also be encouraged to learn self-management skills regarding time spent on the Internet. |

# 2 INTRODUCTION

Over the years, globalization has continuously influenced and transformed the seafaring profession.[1] By virtue of its global nature, this career path requires seafarers to sail across oceans many miles from home. The cumbersome nature of seafaring, and the separation from of families for several months caused by their call of duty, creates challenges in their social life, resulting in psychosocial as well as OSH consequences. Seafarers face occupational challenges, such as disasters and accidents; piracy attacks; limited onboard treatment opportunities for cardiovascular diseases; a high level of work-related stress factors, such as fatigue, isolation and a multinational crew; limited opportunities for recreation; communicable diseases; and occupational cancer.[2] Moreover, the emotional experience of remaining on these "floating homes and work spaces" equates to residing in a totally different universe. While some seafarers adjust to these hardships while familiarising themselves with their duties, challenges such as homesickness, seasickness, long-distance relationships, difficulty in adapting to living conditions shared with other crew members, and fatigue were identified as the most prominent issues faced by newly-recruited seafarers.[3] Seafarers are generally so preoccupied with the wellbeing of their spouses, children, parents, siblings, and friends that it poses risks to their mental health and intellectual sanity. A study by Thomas et al.[4] concluded that separation from family members is the main cause of stress among seafarers, and Oldenburg and Jensen[5] found that "good" communication with family members at home was critical to mitigating the feelings of stress and mental pressures seafarers encounter while on duty and separated from their families.[6]

Moreover, the tension inflicted by the COVID-19 pandemic was one of several issues that caused confusion among on-duty seafarers and increased their desire to remain in close contact with family back home. The opportunity to remain connected with family members and loved-ones is an important element in keeping seafarers happy and in a sound mental state. According to the latest Seafarers Happiness Index for Q1 2021, seafarers are happy that Internet connectivity is improving. Among all issues, Internet connectivity has been the core concern of seafarers to arise from the consequences of the COVID-19 pandemic.[7,8]

States have advocated for Internet connectivity through the United Nations (UN). For instance, the United Nations Human Rights Council adopted a non-binding Resolution on Human Rights on the Internet. The resolution centres on "the promotion, protection, and enjoyment of human rights on the Internet". The resolution not only promotes Internet accessibility, it also promotes Internet affordability and reliability (Article19, 2021).[9] Through the Human Rights Council, the main core group of flag States, notably, Brazil, Nigeria, Sweden, Tunisia and the United States as well as 70 countries from all regions, adopted the resolution with a strong majority. The United Kingdom's department for digital, culture, media and sports declared, in 2017, that Internet access is a legal right, like water and electricity, rather than a luxury. The importance of the Internet is evident from the fact that Internet connectivity has become a requirement among seafarers when considering an employment contract[10]. Although seafarers are satisfied with their profession, adequate access to communication facilities influences their retention in the profession.[11]

The importance of Internet access from the perspective of seafarers is well-known and acknowledged by shipowners and law-making organizations. Shipowners recognize that when attracting the best crew members, the provision of shipboard TV and Internet is an absolute necessity[12] "Who wants to be stuck for weeks on an offshore vessel without being able to connect to friends and family on Facebook when off duty? And who wants to spend their holiday on a cruise liner where you can't check your emails or watch your favourite team in the Champions League?".[13] Mark Dickinson, Vice Chair of ITF stated that "being able to keep in touch with family and friends isn't just a nice-to-have, it's a basic human right. That's why we fought so hard for seafarers to be given Internet access and to have a mandatory provision in the MLC." The MLC is an international convention established to protect seafarers' rights and has been ratified by more than 100 countries, who represent over 90% of the world fleet. One of its provisions is that governments, shipowners and seafarer representatives must meet periodically to keep the Convention under review and up to date. The latest Special Tripartite Committee (STC) meeting in Geneva on 13 May 2022 concluded with an agreement on a number of changes, including a commitment to better social connectivity for seafarers.[14] Despite the recognized importance of allowing seafarers and their families to maintain online communications, not all shipping companies currently offer shipboard Internet. Despite ships already having the technology to provide Internet access, shipowners have dug their heels in over the change. They have insisted that they should be able to limit access and charge seafarers for Internet connectivity. However, the Seafarers Group lobbied to ensure that any charges levied on seafarers remain an exception and that any imposed charges should be reasonable. Governments have also been encouraged to increase Internet connectivity in ports and associated anchorages without cost to seafarers.

Decades ago, seafarers had to wait until arriving at their ports of call to contact their families. Satellite phones were introduced in the 1990s, which seafarers perceived as expensive due to their low income. Apart from the cost involved, a very limited number of households had telephones, which additionally caused this medium of communication to be of limited value within the seafaring community. Letter writing was the norm and widely used by seafarers to communicate with their families and loved ones. However, sending and receiving letters was time consuming. Serving as communications bearers, shore-based personnel from shipping companies would board docking ships to facilitate the dispatch of letters from seafarers to their families. The whole process of communication could take between 30 to 45 days.[15]

As technology advanced around the 2000s, emails became the main mode of communication, which was free of charge, though connections were very slow. Satellite calls were very costly (about 2 US$ per minute), which meant seafarers would only make two or three short calls per week. The use of SIM cards also grew in popularity during this period. Whenever ships arrived at port, agents would arrange local SIM cards for the seafarers so they could contact their families and loved ones. This service is still provided in situations where companies are unable to offer seafarers good Internet connectivity. Between 2010 and 2020, technology advanced. All electronic means of communication had become better and cheaper. Shipping companies upgraded their communications to enhance seafarer connectivity with their families. However, only major companies offered such facilities, so seafarers in smaller companies still had to make costly satellite phone calls.[16]

The newest technology at the time, the Internet, became more advanced and offered greater speed. This boosted communications within the seafaring world. With the help of high-speed Internet and the creation of various social media platforms, such as Skype, WhatsApp, Facebook, Instagram and others, seafarers could make video and voice calls with their families at any time and connect with the wider world.[17]

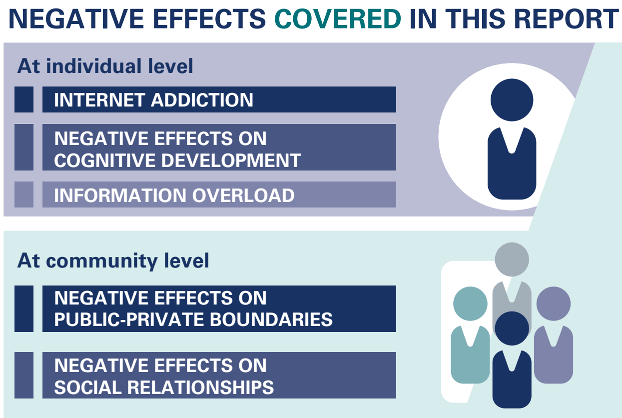
### THE POSITIVE EFFECTS OF INTERNET USE

The arrival of onboard high-speed Internet has had a positive impact on the wellbeing of seafarers and has facilitated their communications with loved-ones. Internet connection has become key to job retention among seafarers, while shipping companies actively use this service to make the jobs on board more attractive.[18] Moreover, being connected with the wider world is highly desired by seafarers. With social media having become such an integral part of our lives and a major source of information sharing, simply being connected with the world makes the crew feel much less isolated from the outside world. Furthermore, the Internet offers unlimited opportunities to manage everyday life, such as handling finances and online purchases. Access to quick regulatory updates and downloading necessary documents via the Internet also makes a seafarer's life easier.[19]

### THE POTENTIAL RISKS OF EXCESSIVE INTERNET USE

Despite the evident advantages of shipboard Internet, the flipside of Internet connectivity is the devastating impact it risks having on the OSH of seafarers if not used appropriately. The negative impacts include: negative

FIGURE 5.4.1 Potential side effects of the excessive use of Internet[a]




cognitive development, information overload, Internet addiction, negative effects on public/private boundaries and spheres of living, negative effects on social relationships and communities.[20] Shakki et al.[21] concluded that one of the most important negative impacts of online social networks is the intense involvement of employees in these platforms and the subsequent negligence of their organizational duties and tasks.

Another investigation found that not only does onboard Internet access pose both advantages and disadvantages to the wellbeing of seafarers, total absence of or limited access to the Internet also causes some level of stress. Jensen[22] found that unavailability or limited availability of shipboard Internet results in pressures related to searching for other means of communication. A typical example is the cost involved in the purchase of SIM cards at the ports of call, which seafarers consider as the last resort when there is an absence of shipboard Internet. Seafarers are not only worried about expenses but also feel targeted by potential scammers when purchasing SIM cards that in reality do not offer the minutes, speed or data promised, hence the term "mafia" being use in reference to SIM card vendors. Another cause of stress to seafarers is inflicted by family members, especially those who may also not have Internet access.[23]

Previous research on shipboard Internet has highlighted the importance of Internet connectivity to the wellbeing and welfare of seafarers. However, no studies have thus far explored the influence of excessive use of the Internet in relation to the OSH of seafarers. Therefore, this study looks at both sides of the coin, investigating both the positive and negative impacts of Internet use on the OSH of seafarers.

[a] This report does not cover the following negative side effects: Cybercrime, cybersecurity, negative effects on privacy, negative effects on knowledge and belief, negative effects on democracy and social cohesion, negative effects on specific social institutions, etc. In addition, this study does not cover physical side effects such as poor ergonomic posture.

# 3 RESULTS OF THE SURVEY

The seafarers who responded to the survey are mainly nationals from Bangladesh, Colombia, Costa Rica, Croatia, Georgia, Republic of Iran, Mexico, Panama, the Philippines, Romania, Spain, Ukraine, and Venezuela. Of the total respondents, 90% are male and only 5% are female as shown in figure 5.4.2. A total of 34% are aged between 25-34, 23% between 18-24, and 23% are aged between 35-44 (Figure 5.4.3).

FIGURE 5.4.2 Gender

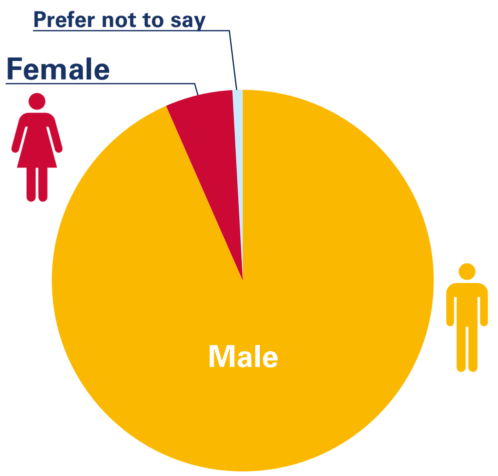
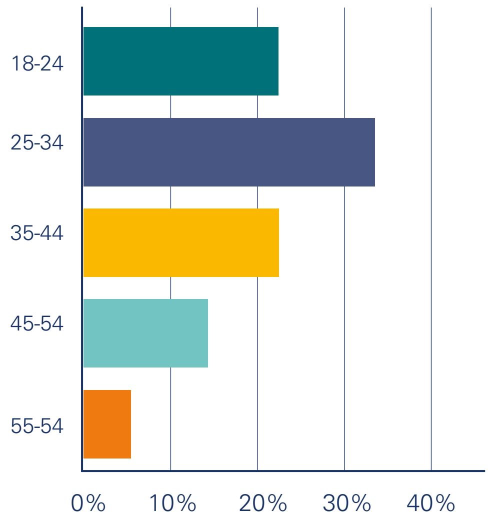


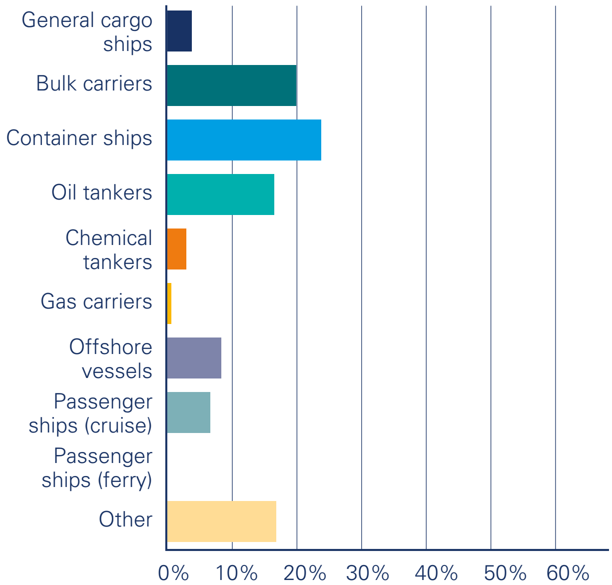

FIGURE 5.4.3 Age




The survey was completed by seafarers working on different kinds of ships flying the Panamanian flag (Figure 5.4.4).

Figure 5.4.4 shows the types of ships the respondents work on:

FIGURE 5.4.4 Types of ships the respondents work on



## 3.1 INTERNET ACCESS AS A WORK FACTOR ON SHIPS

The research questionnaire asked seafarers working on Panamanian ships how important being connected to the Internet is while serving on board. Among the 239 received answers, 55% of seafarers responded that it is crucial, 31% very essential, 12% important and only 0.42% not important at all (Figure 5.4.5). These results indicate how important Internet access is to seafarers. In addition, the respondents were asked if they consider shipboard Internet accessibility as critical for accepting a work contract. A total of 80% responded positively, and only 21% responded negatively (Figure 5.4.6). There is therefore no doubt that Internet access is a retention criterion among seafarers.

In addition, around 68% of respondents stated that their company provides them with Internet access for personal use on board, whereas approx. 31% responded that their company does not grant them Internet access, which is a high rate (Figure 5.4.7).

FIGURE 5.4.5 Q: How important is it for you to be connected to the Internet while on board?

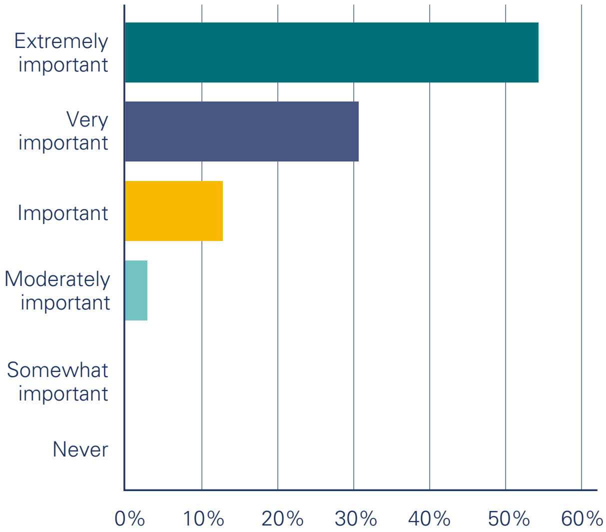



FIGURE 5.4.6 Q: Do you consider Internet accessibility on board ships to be critical when considering a work contract?

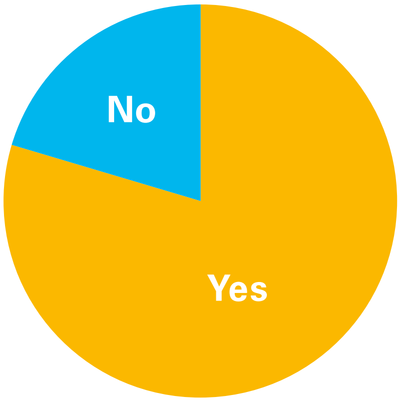
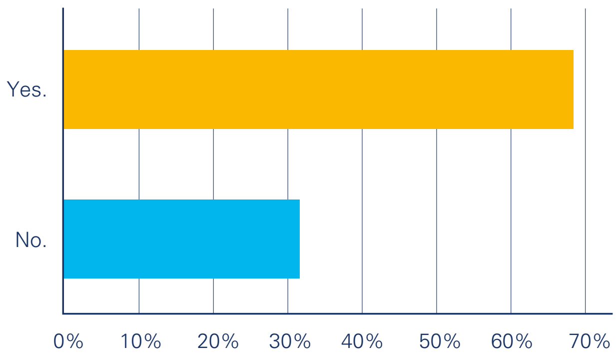
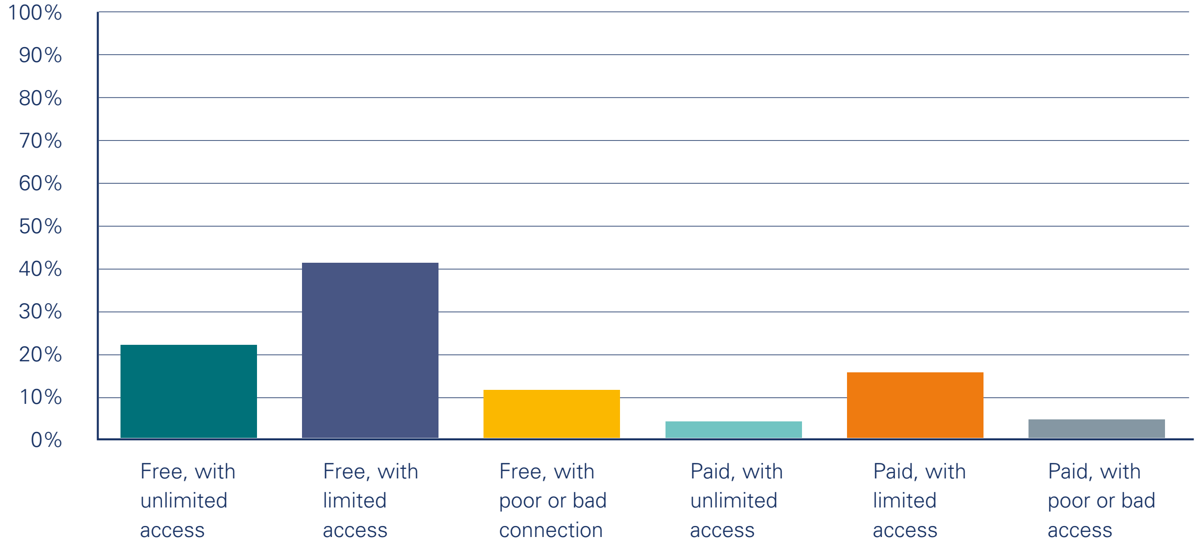



FIGURE 5.4.7 Does your company provide you with Internet access for your personal use on board?



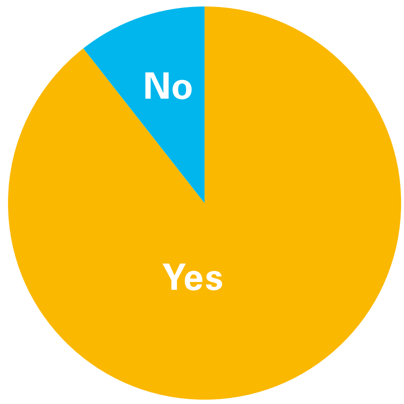

However, in response to the question of whether the company provides Internet access either at no cost or for a fee, only 22% of the 222 received responses confirmed having free and unlimited access to the Internet. Around 41% confirmed having Internet for free but with limited access, and 11% had access for free but with a poor connection. Among those paying for Internet connection, 4% of 222 respondents stated that their paid-for Internet is with unlimited access, 15% paid for Internet although had limited access, and 5% paid for a poor connection (Figure 5.4.8).

FIGURE 5.4.8 If your company provides you with Internet, is it free or do you pay for it?




Results also show that for those out of a total of 235 respondents whose company does not provide Internet connection, approx. 88% purchase SIM cards to be connected to the Internet, and only 12% do not buy SIM cards (Figure 5.4.9). It is worth noting that purchasing SIM cards is not always easy for seafarers, nor is it affordable for everyone, especially among the ratings. Some seafarers call rogue SIM card vendors the "mafia". Seafarers are therefore exposed to pressures simply as a result of SIM card purchase.[24]

FIGURE 5.4.9 If your company does not provide you with Internet, do you buy data SIM cards to be connected to the Internet?



## 3.2 INTERNET QUALITY AND ITS INFLUENCE ON THE MENTAL HEALTH OF SEAFARERS

Even where shipboard Internet is available, the results of the survey show that 42% of the total of 235 respondents sometimes feel stressed, anxious or depressed if the connection is unreliable. Approximately 21% of respondents generally feel unaffected, and around 14% always feel stressed, anxious, or depressed when the Internet connection is poor or unreliable. The results also show that 11% of the respondents rarely feel anxious, stressed or depressed when the connection is poor, and 12% do not experience any sign of anxiety or stress when the Internet connection is poor (Figure 5.4.10).

The same applies when respondents have no access to shipboard Internet. Approximately 41% of respondents sometimes feel stressed, anxious, or depressed. 20% of the respondents generally feel unaffected, and only 13% of respondents never experienced feeling stressed, anxious or depressed when not having access to shipboard Internet. Around 11% rarely feel stress, anxiety or depression when not having access the Internet (Figure 5.4.11).

FIGURE 5.4.10 When your Internet connection on board is not reliable, do you feel stressed, anxious or depressed about it?

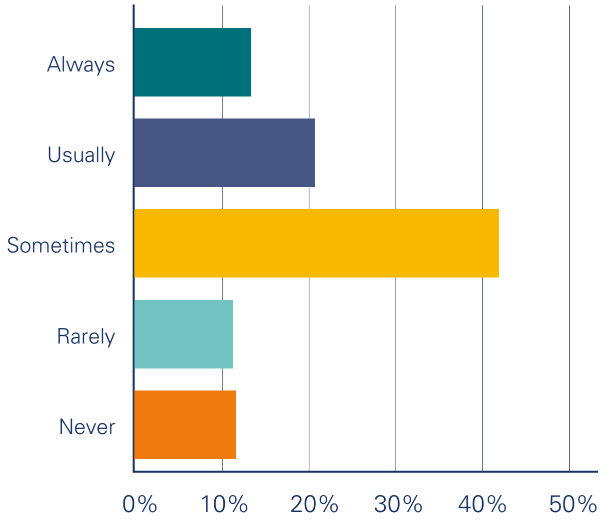
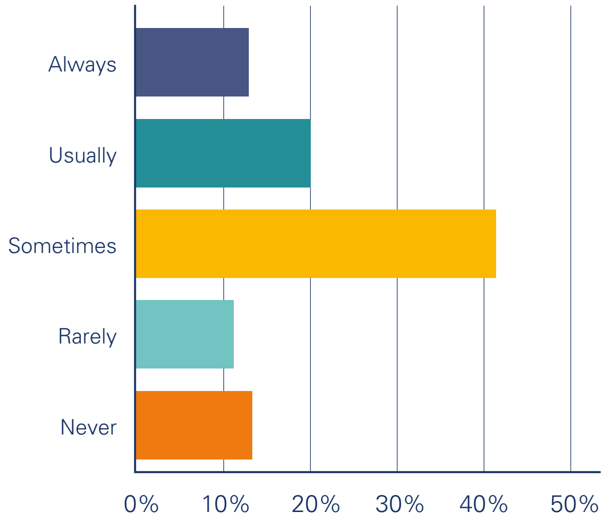



FIGURE 5.4.11 When you are unable to access the Internet on board, do you feel stressed, anxious or depressed?

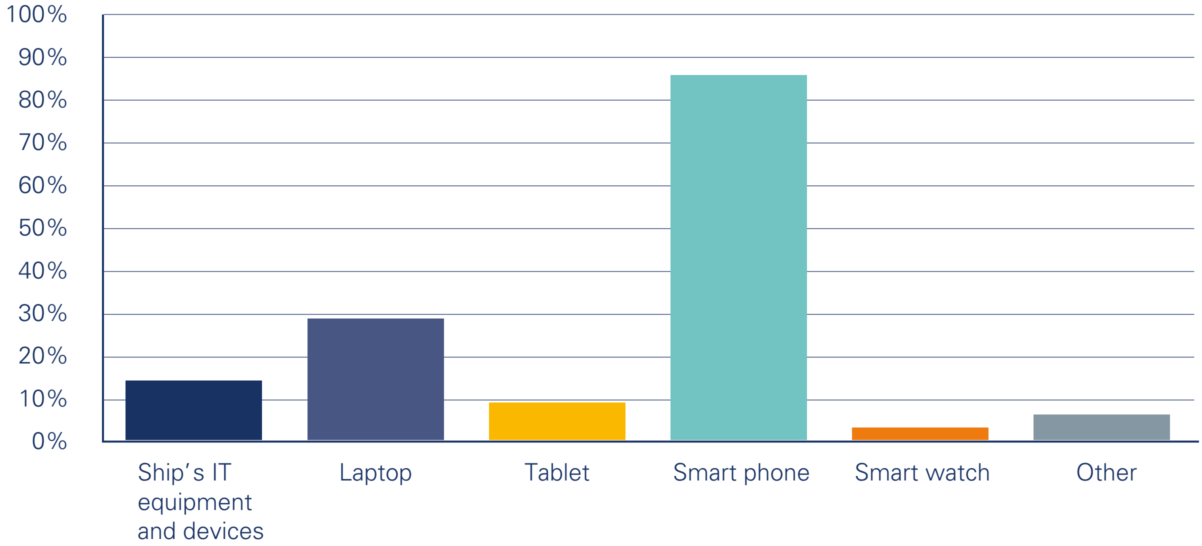



These results indicate that Internet access, somehow, influences how seafarers feel on board. The state of mind of most respondents is affected by whether they have Internet access or not, and by the quality of the connection.

## 3.3 INTERNET ACTIVITIES OF SEAFARERS AND THEIR POTENTIAL OSH RISKS

The results of the study indicate that most respondents access the Internet using their mobile phones, i.e. approx. 86% out of 230 responses. A total of 29% access the Internet using their laptop, and only 14% use the ship's IT equipment or devices (Figure 5.4.12).

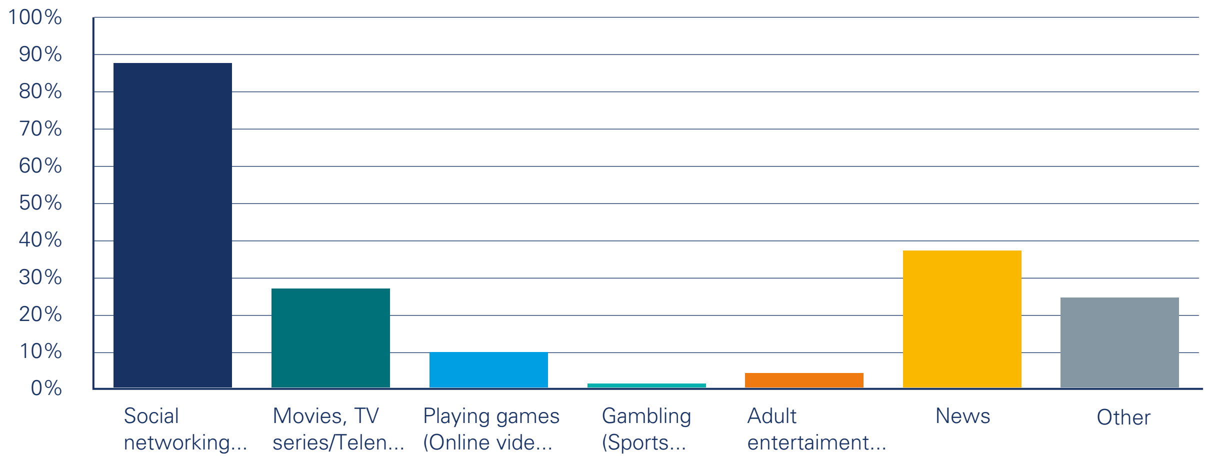
FIGURE 5.4.12 Which of the following devices do you use when connecting to the Internet while on duty on board?




Based on additional discussions with seafarers, this latter percentage could be explained by the fact that seafarers have few opportunities to use shared IT facilities to connect to the Internet and therefore also have less opportunity to interact with other co-workers.

Regarding their choice of online activities, approximately 88% of the 236 respondents reported using the Internet to connect to social media, while 37% check the news and 27% use it to watch movies and TV series. Around 9% use it to play games, and only 4% access adult entertainment. Finally, 24% of the respondents use the Internet for other activities (Figure 5.4.13).

FIGURE 5.4.13 For which activity do you use the Internet?




These survey results indicate that the respondents mainly use the Internet to access social media, which may be their only means of remaining in contact with their families and friends. No doubt, excessive use of social media may cause health risks (physical or mental), which is why raising awareness about its appropriate use is essential for maritime companies and authorities.

## 3.4 INTERNET USE AND PERSONAL TIME MANAGEMENT

### 3.4.1 TIME SPENT ON THE INTERNET

When asked at what time of day they use the Internet, almost 70% of respondents reported accessing during night time, while 29% stated during daytime (Figure 5.4.14). The average time spent on the Internet is estimated to be 2 to 3 hours per day for 26% of the respondents, 3 to 4 hours for 21%, and 4 hours or more for almost 17% of the respondents.

These responses clearly warrant further discussion on how these online hours are calculated by our respondents, such as whether they access the Internet for a long period of time or simply from time to time during the day. Nevertheless, if most respondents use the Internet during night time then with the above-mentioned number of hours, their online habits may raise concerns about adequate time for rest and sleep (Figure 5.4.15).

FIGURE 5.4.14 When do you use the Internet the most?

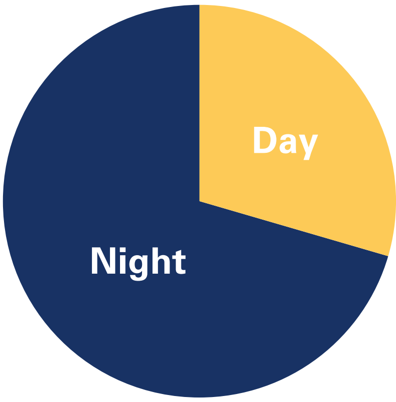
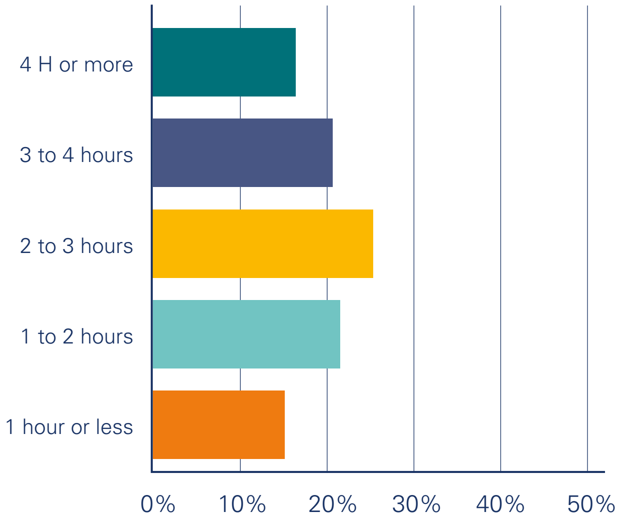



FIGURE 5.4.15 What is your average time spent on the Internet per day?



When responding to the question regarding to which extent they lose sleep because of their Internet use, the answers of the respondents were directly related to those given to the previous question on what time of day they access the Internet. Almost 26% out of 235 respondents said they sometimes lose sleep due to online activity, 6% usually do so, and approximately 3% always lose sleep. In addition, 33% said they rarely lose sleep because of the Internet, while 33% never do (Figure 5.4.16).

Likewise, the respondents were asked how often they neglect their rest time to spend time online. Approximately 26% of respondents stated that they sometimes neglect their rest time to spend time online, almost 5% usually do so, and only 2% consistently neglect their rest time to spend more time online. However, 38% said they rarely fail their rest time in favour of online activity, and almost 29% never do so (Figure 5.4.17).

FIGURE 5.4.16 How often do you lose sleep due to being online?

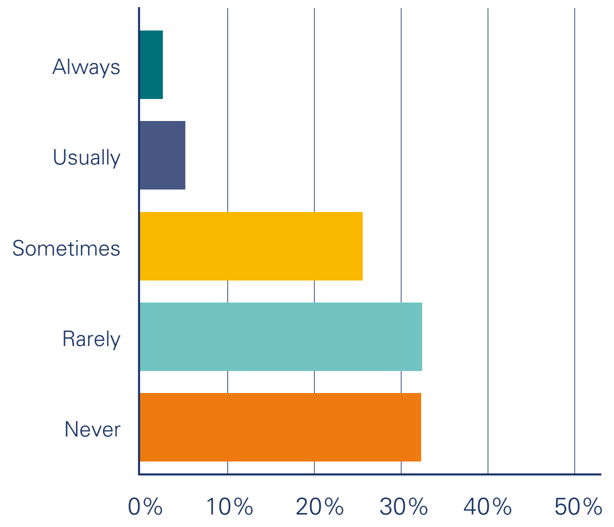
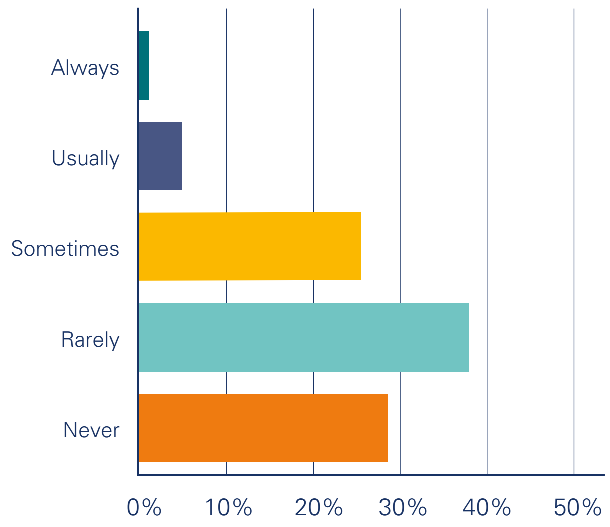
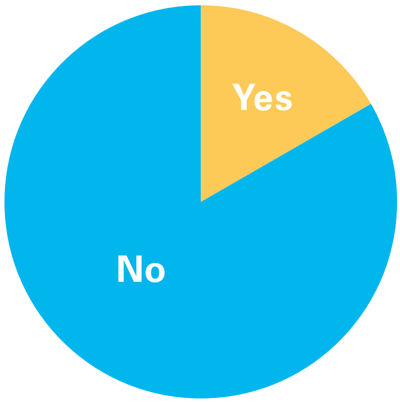



FIGURE 5.4.17 How often do you neglect your rest time to spend more time online?




The respondents were also asked if they feel tired while on duty as a result of their Internet use. A total of 86% out of 227 respondents reported not doing so, whereas almost 17% of respondents confirmed feeling tired (Figure 5.4.18).

FIGURE 5.4.18 Do you feel tired while working due to having spent time on the Internet?



### 3.4.2 INTERNET USE AND DISTRACTION FROM WORK

In a further study of Internet use as a distraction, respondents were asked if notifications from their smart devices distract them while working. A total of 85% out of 228 respondents reported not being distracted, whereas 15% of the respondents said they were (Figure 5.4.19).

Regarding the overload of information that Internet use may cause, 78% of respondents answered that they do not experience an information overloaded resulting from Internet use, whereas 22% answered that they do (Figure 5.4.20).

FIGURE 5.4.19 Do you get distracted by notifications from your smart devices while you are working?

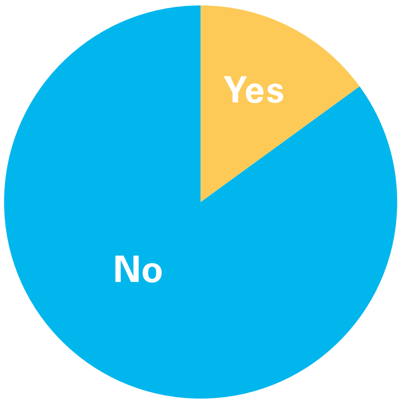
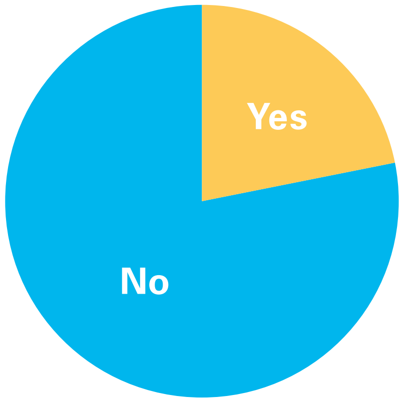



FIGURE 5.4.20 Do you feel overloaded with information (personal and work-related) due to Internet use?




### 3.4.3 MANAGING TIME SPENT ON THE INTERNET

One of the questions in the survey asked respondents how often they stay online longer than intended. Approximately 49% out of 234 respondents answered they sometimes stay online longer than intended, 16% said they usually stay longer online, and 7% always stay longer online than intended. Finally, 20% of the respondents expressed rarely exceeding their intended time of Internet use (Figure 5.4.21).

The respondents were also asked to which extent they believe they can control their urge to surf the Internet. In total, 35% out of 233 respondents reported being able to control their urge to a moderate extent, 24% believed they could completely control their Internet use, and approx. 18% maintained they could to a large extent. Almost 14% said to a minimal extent, and 9% not at all (Figure 5.4.22).

FIGURE 5.4.21 How often do you find that you stay online longer than you intended?

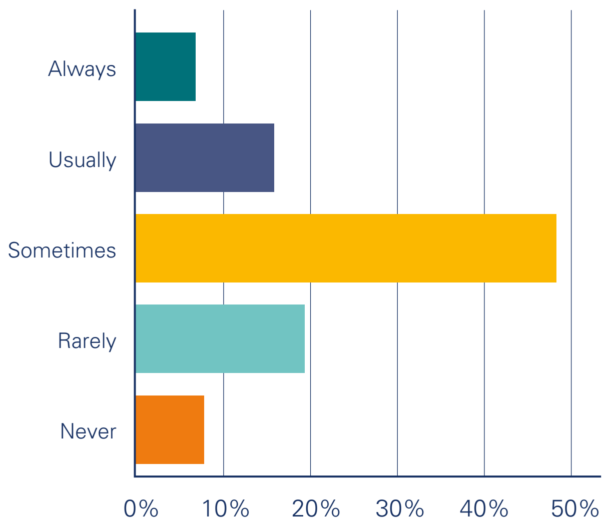
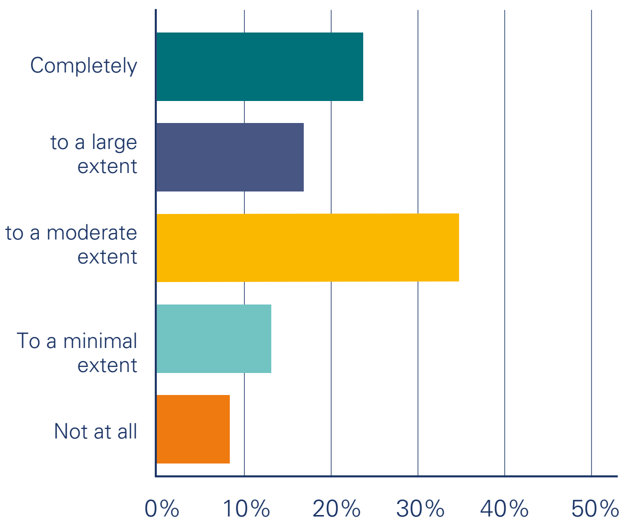



FIGURE 5.4.22 To what extent do you think you can control your desire to surf the internet?



# 4 INTERNET USE AND ACCIDENTS

The respondents were asked if Internet notification caused them any accidents at work. Almost 90% out of 229 responded said they do not cause accidents, whereas 10% said that they did (Figure 5.4.23).

The same question was posed to investigate whether any of their co-workers had experienced an accident caused by being distracted by Internet notifications, and almost 87% said this was not the case, whereas almost 13% confirmed such a correlation (Figure 5.4.24).

FIGURE 5.4.23 Has the distribution of Internet notifications ever caused you any work accidents?

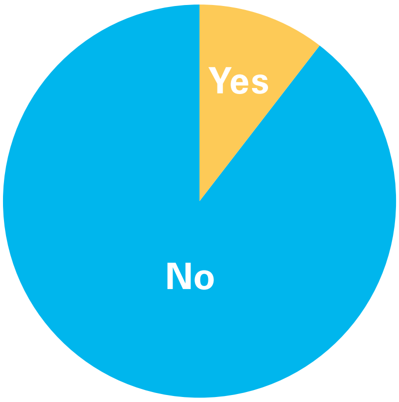
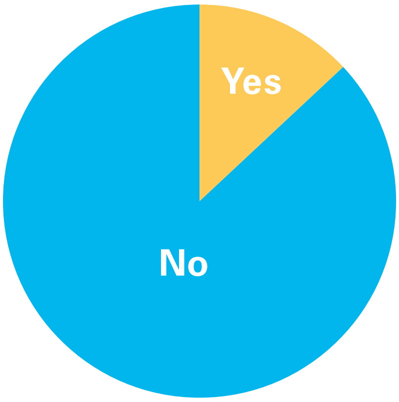



FIGURE 5.4.24 Has the distribution of Internet notifications ever caused any of your co-workers any work accidents?



# 5 SOCIAL ATTITUDES TOWARDS THE INTERNET

Furthermore, the respondents were asked whether they think that life without the Internet on board would be boring, empty and joyless. Almost 31% of the 230 respondents strongly agreed, 37% agreed and 20% were indifferent to the question, whereas 11% disagreed and only 1% strongly disagreed (Figure 5.4.25).

To gain further information about social attitudes towards Internet use on board, the respondents were asked if they get defensive when someone tells them they spend too much time online. A total of 20% said occasionally, 8% frequently, 4% often, and almost 3% always do. 43% said never, and approximately 22% rarely do (Figure 5.4.26).

FIGURE 5.4.25 In your opinion, would life on board without the Internet be boring, empty and joyless?

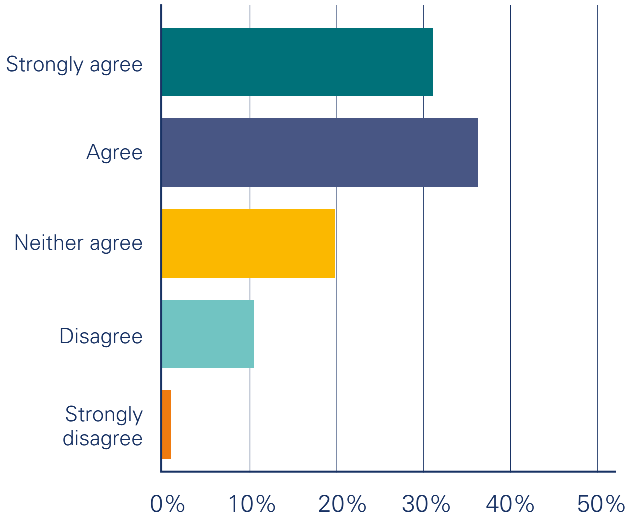
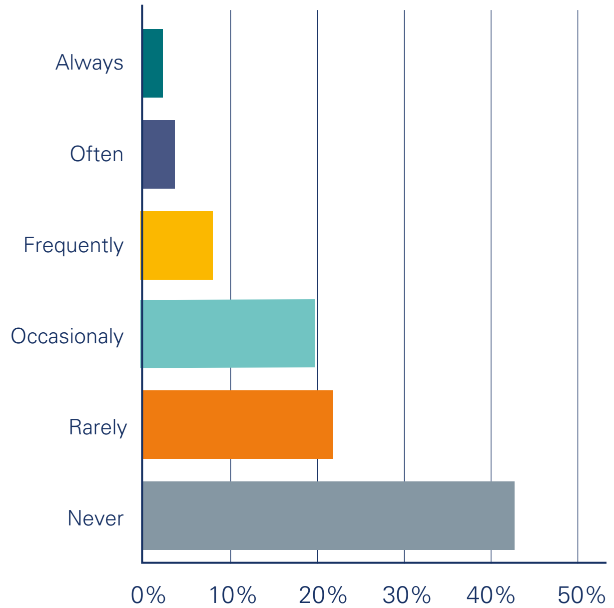
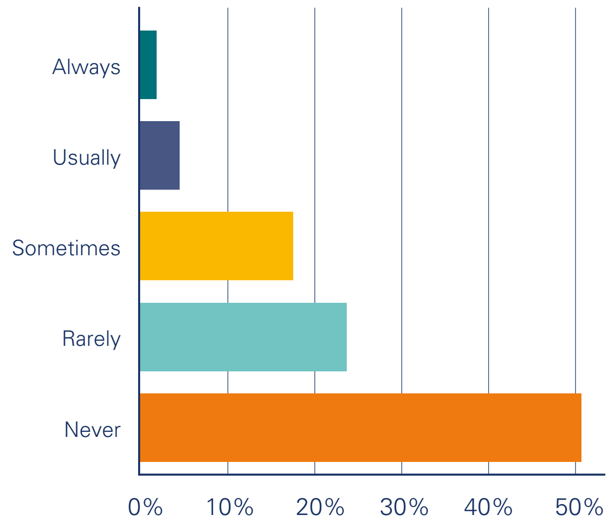



FIGURE 5.4.26 Do you get defensive when someone tells you that you spend too much time online?




Additionally, the respondents were asked if they snap, yell or get annoyed if someone bothers them while they are online. Approximately 51% said they never did, 24% said they rarely did, and approximately 18% said sometimes. 2% confirmed always doing so, and 5% said usually (Figure 5.4.27).

FIGURE 5.4.27 How often do you snap, yell, or act annoyed if someone bothers you while you are online?



# 6 ONBOARD SOCIAL ACTIVITIES

The place the Internet has among the social activities of seafarers on board was also studied. One questions posed was whether seafarers use the common social facilities on board to watch TV, movies or series/telenovelas with their co-workers. Approximatively 46% stated that they sometimes do, 22% usually, 11% always, 13% rarely, and 8% never use the common social facilities (Figure 5.4.28).

Another question posed was whether the seafarers engage with gaming or games with their co-workers. A total of 39% said sometimes, almost 22% said usually, 10% said always and 14% said never (Figure 5.4.29).

FIGURE 5.4.28 Do you use onboard common facilities to watch TV, movies or series/Telenovelas with your co-workers?

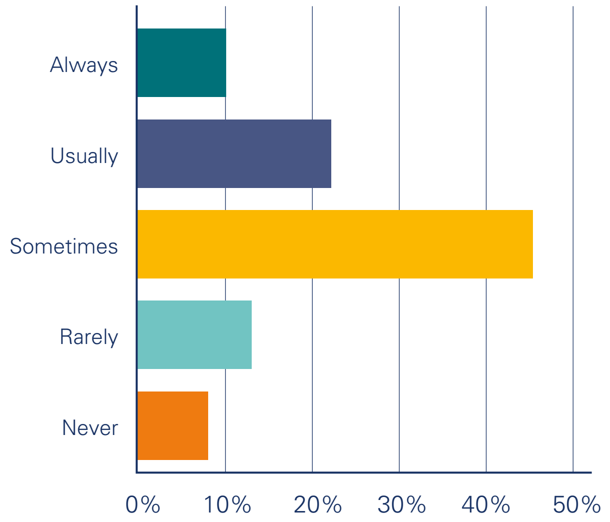
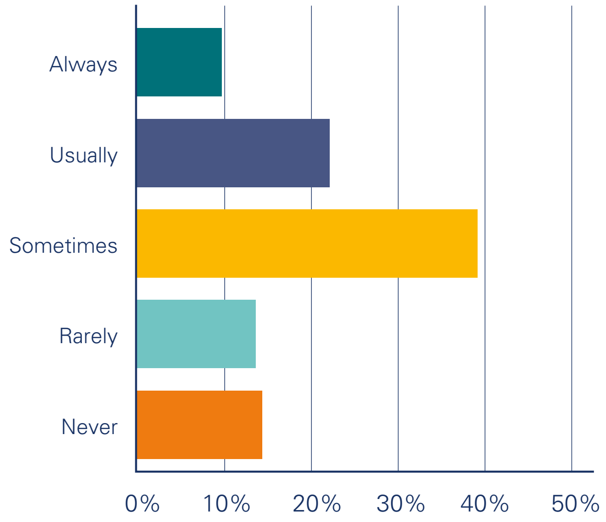
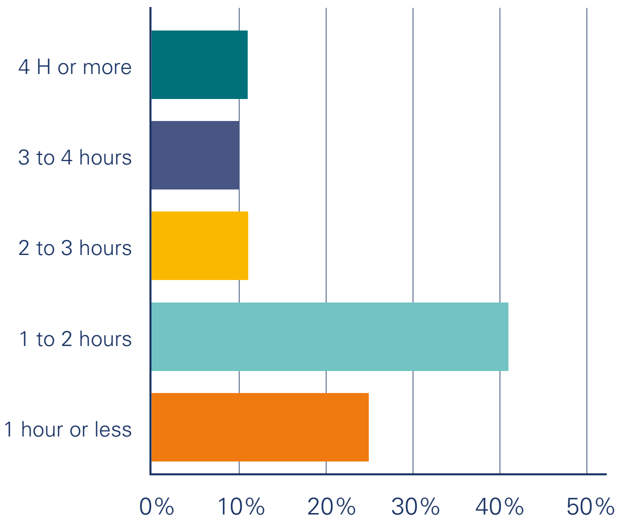



FIGURE 5.4.29 Do you spend time gaming with or playing games with your co-workers?




When asked whether they spend some of their rest time on physical activities or reading, 41% of the respondents stated that they spend between 1 to 2 hours on physical activity, almost 25% said 1 hour or less, and 11% stated 2 to 3 hours (Figure 5.4.30).

FIGURE 5.4.30 How many hours of your rest time do you spend on physical activity?



Regarding book reading on non-electronic devices, 48% of the respondents spend 1 hour or less, almost 32% spend 1 to 2 hours, and 13% spend 2 to 3 hours. In a follow-up to this specific question, the respondents were additionally asked if their company provides them with a library. A total of 62% of the respondents said no, and almost 38% said they had access to a library (Figures 5.4.31 and 5.4.32).

FIGURE 5.4.31 How many hours of your rest time do you spend on reading books on non-electronic devices?

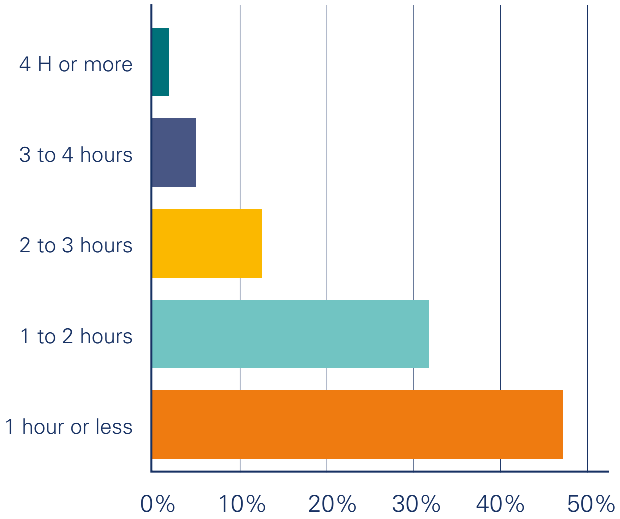
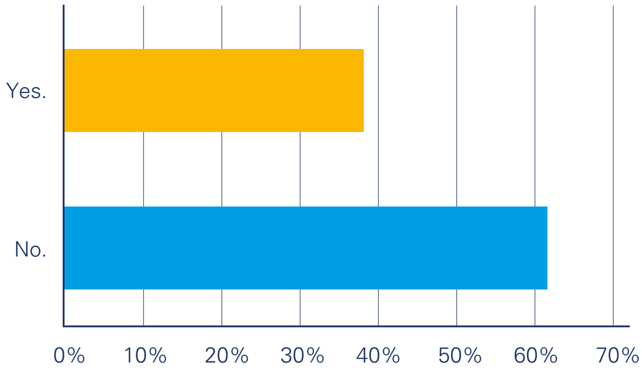



FIGURE 5.4.32 Does your company offer you a library?




When the seafarers were asked whether they prefer spending their rest time socialising with co-workers or socialising online, more than 58% of respondents stated preferring to socialise with co-workers, and almost 42% preferred to socialise online instead (Figure 5.4.33).

In addition, the respondents were asked if their company undertakes regular initiatives to provide social activities on board to support interaction between co-workers. Almost 58% of respondents said that they do, and approximately 42% of respondents reported this not to be the case. Around 60% of respondents confirmed that their company encourages them to participate in social activities on board, and around 40% of respondents stated that this was not the case (Figure 5.4.34).

FIGURE 5.4.33 Do you prefer to spend your rest time socialising with co-workers or socialising online?

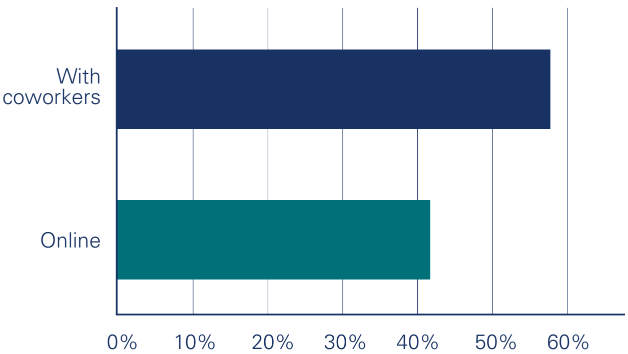
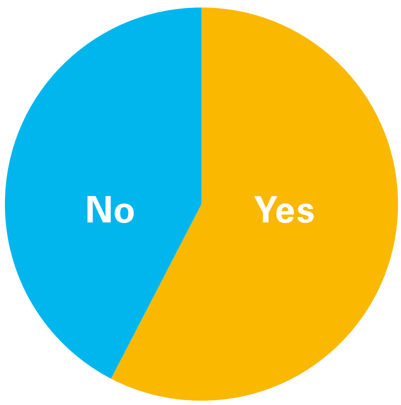



FIGURE 5.4.34 Does your company take regular initiatives to provide social activities onboard?



In the same line of inquiry, the respondents were asked whether they would like their company to make a greater effort in organising social events on board. Around 78% would like their company to organize events, whereas 22% of respondents said they do not (Figures 5.4.35 and 5.4.36).

FIGURE 5.4.35 Does your company encourage you to participate in social activities on board?

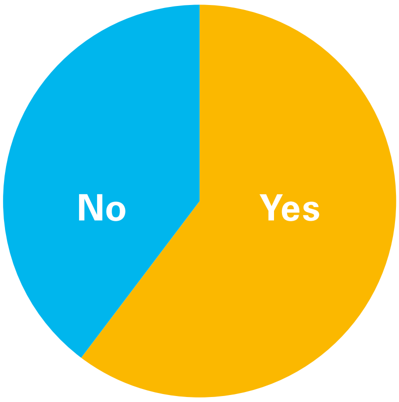
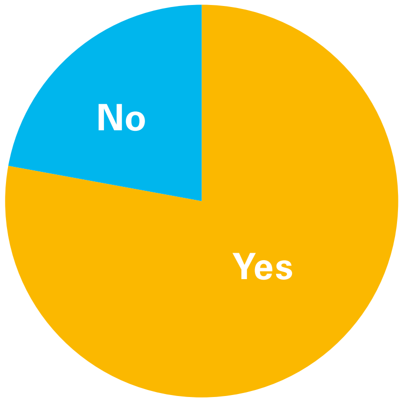



FIGURE 5.4.36 If not, would you like your company to make more of an effort to organise social events for you?



# 7 AWARENESS OF THE NEGATIVE EFFECTS OF INTERNET USE

The respondents were also asked if they are aware of the potential mental health risks of the excessive use of the Internet. Approximately 81% of respondents said they were, and 19% said they were not (Figure 5.4.37).

When asked whether they have ever attended any courses about the mental health risks of the excessive use of the Internet, 68% said that they have never attended such courses, and 32% said they had (Figure 5.4.38).

FIGURE 5.4.37 Are you aware of the negative effects of the excessive use of the internet?

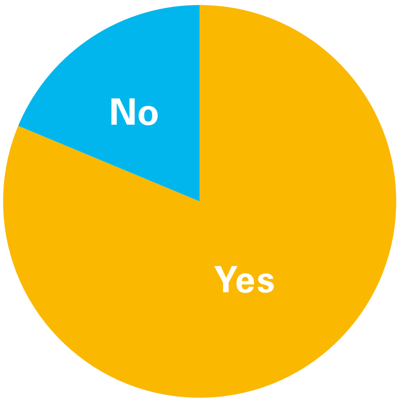
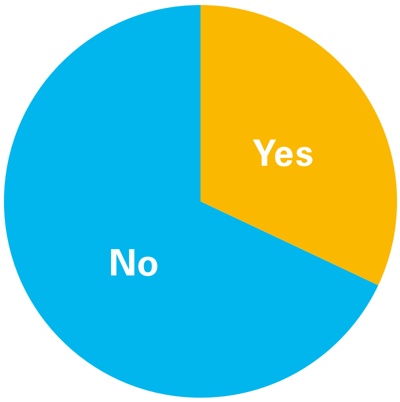



FIGURE 5.4.38 Have you ever attended a course about the possible mental health risks of excessive Internet use?




The last question of the survey concerned whether the company provides them with information about the risks of excessive use of the Internet. Around 44% out of 229 respondents replied that they had, and 56% stated not having received such information (Figure 5.4.39).

Those stating that they had not received such information were given a follow-up question on whether they would like their company to provide them with such advice. A total of 72% of the respondents answered affirmatively and only 28% answered that they would not like to be provided with advice (Figure 5.4.40).

FIGURE 5.4.39 Has your company provided you with any information on the negative effects of excessive Internet use?

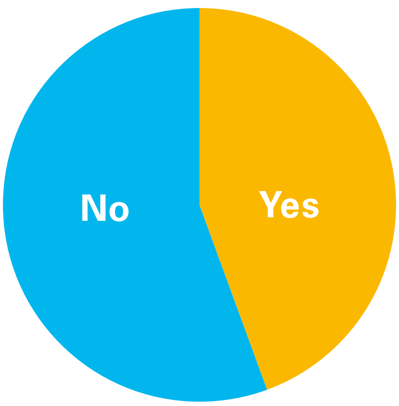
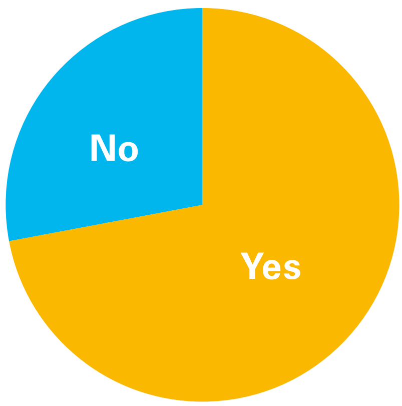



FIGURE 5.4.40 If not, would you like to receive advice on such matters?



# 8 CONCLUSION AND RECOMMENDATIONS

The results of the survey indicate that seafarers, like other workers, need high-quality Internet. Most seafarers use the Internet to connect to the rest of the world through social media.

The survey also indicates that there are no signs of Internet addiction by seafarers on board and that most seafarers are aware of the negative side effects of excessive Internet use. Most seafarers manage their Internet time well, and their onboard Internet use does not affect their work.

The results indicate that while the quality of Internet connection is arguably an important factor influencing the retention of seafarers, poor Internet quality, on the other hand, may be a source of stress, anxiety and depression among seafarers.

Another significant finding is that seafarers still prefer and desire to spend time with their co-workers and on social activities, and that most of them welcome any social activities the shipowners can provide.

Determining the positive and negative aspects of shipboard Internet use, based on the above analysis of responses from 239 seafarers working on Panamanian-flagged ships and interviews with three seafarers, the report gives rise to three recommendations:

| | |
|---|---|
| 1 | Like all other workers, seafarers should be provided with unlimited access to high-quality Internet connections. This study indicates that poor Internet quality, or a lack of Internet access, results in negative mental health effects on board. Advocating for high-quality shipboard Internet among shipowners and flag States could help minimize stress and maximize social relations among seafarers on board. |
| 2 | Shipowners should provide facilities and encourage an environment where seafarers engage in more social activities with their onboard co-workers. They should actively solicit ideas for social activities from seafarers. |
| 3 | There should be an awareness campaign among seafarers about the potential harmful side effects of the excessive use of the Internet on board (as at any other workplace). Seafarers should also be encouraged to learn self-management skills in terms of time spent on the Internet. |

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CHAPTER 6

# CONCLUSIONS

6

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This report focuses on the impacts of new advanced technologies on seafarers. Based on our literature analysis and the undertaken surveys, workshops and fieldwork, this report provides several unique outputs, most notably a Technology Road Map (section 2.4) and skill foresights (section 3.1). Participating in our research is a range of stakeholders, including seafarers, shipping companies, crewing agencies, technology providers, trade unions, maritime education experts, and policymakers among others.

The Technology Road Map presented in this report offers comprehensive insights into future industrial technologies and their evolution in the maritime industry. Divided into short, medium and long-term expectation horizons, the Technology Road Map covers industry trends within main and sub-technologies, including the relevant policies, opportunities and threats they respectively entail, as reported by key stakeholders. The Technology Road Map thus presents itself as a useful tool for all stakeholders, supporting them with the identification of and preparation for the future challenges of an industry undergoing profound technological change.

The seafarer skill foresights presented in this report are aligned with the Technology Road Map. The technological transition in the maritime industry will affect seafarers differently depending on their profession, rank and job function. This report has aimed to cover all seafarers concerned since the technological transition will affect everyone in the industry, whether working on a management, operational or support level, i.e. as deck and engine officers, ratings or steward staff. However, some sections of this report, such the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) gap analysis, narrowly focus on STCW-certified seafarers. Indeed, while the Technology Road Map primarily deals with automation and technology transition, the seafarer skill foresights consider a wider scope of technological developments within smart and green shipping that will affect the future of work at sea.

Upskilling and reskilling are important interventions in support of seafarers in the light of the rapid change their working environment is set to undergo due to the advancement of smart and green shipping. The importance of training has been highlighted throughout this report. The training support offered to seafarers by shipping companies and governments is, indeed, critical to the success of the transition towards automation and digitalization. Widely affecting the future careers of seafarers, the technological transition in the industry is expected to result in the emergence of a range of new kinds of jobs for seafaring professionals.

To prepare the maritime workforce for the future, all nations will naturally seek to adapt to the challenges posed by advanced technologies and the opportunities they offer. Subsequently, the impact of such new technologies on seafarers will be influenced not only by their individual preparedness for change but also by the conditions offered by each country. Chapter 4 is devoted to the Maritime Country Profiles developed for this report based on five key factors where 23 countries from six regions have been investigated and modelled. The Maritime Country Profiles are furthermore aligned with the Technology Road Map and the skills foresight in this report.

Our research has additionally addressed the impact of advanced new technology in the maritime industry on the Occupational Safety and Health (OSH) of seafarers. Four Country Report case studies have been presented as a thorough investigation into different technology-related OSH issues, such as the risk of automatic surveillance by Artificial Intelligence (AI) and big data (chapter 5.1), technostress (5.2), safety and health concerns on board battery-powered vessels (5.3), and Internet use (5.4). Such externalities resulting from technological advancement require careful attention by shipping companies, trade unions, and policymakers alike to protect seafarers from hazardous work environments that may arise on future ships.

To ensure that this report holds practical value for all stakeholders, specific recommendations drawn from our research are presented in the final section of each chapter. Overall, our two key messages are: 1) the necessity of supporting seafarers with lifelong learning and career development and 2) the importance of ensuring that the adaptation of advanced technology also promotes the health and wellbeing of seafarers. These priorities require addressing the adverse effects of technology that may potentially harm seafarers. It is therefore our hope that all stakeholders in the industry will contribute to designing a maritime future equally beneficial to all by investing in education and training as well as promoting safe working environments for seafarers. This report uses gender-neutral terminologies and images of both male and female seafarers in order to challenge traditional norms and values in the maritime industry and promote gender equality at sea for current and future generations. This report provides the necessary insights and analytical resources to support the Maritime Just Transition,[a] which will require the involvement and commitment of every maritime stakeholder to the future of the industry.

[a] For further information, please visit the Maritime Just Transition Task Force by United Nations Global Compact and its position paper, https://unglobalcompact.org/take-action/think-labs/just-transition/about

# ANNEXES

# ANNEX A

TABLE A1 List of future shipping technologies

| | Main category Techs (Cluster 1) | Sub-category Techs (Cluster 2) | Examples of enabling/enabled technologies | Description (Cluster 2) |
|---|---|---|---|---|
| 1 | **Automation technologies** | **Artificial Intelligence (AI) algorithms** | AI enables the following functions and systems:<br>- Autonomous navigation (virtual captain, sensor fusion, dynamic positioning)<br>- Remote operation and maintenance and repair<br>- Vehicle health management system, condition-based maintenance,<br>- Artificial Intelligence Engineer<br>- Automatic cargo management software<br>- Automatic seaworthiness and stability management software | AI enables machines to perform tasks while exhibiting human behaviour with functions where there is otherwise little or no human intervention. AI processes information by machine and deep learning algorithms and makes decisions autonomously and timely |
| 2 | | **Situational awareness and monitoring sensors (SA)** | The following technologies enable SA: LIDAR, underwater sensors, sound sensors, day and night vision cameras, VR and AR equipment, robots, drones, alarm sensors | To sense, gather, and process data form internal systems and external environments using LIDAR, underwater sensors, sound sensors, day and night vision cameras, VR and AR equipment, robots, drones, and alarm sensors |
| 3 | | **Advanced Actuators (AA)** | AA enables the automation following functions and systems:<br>Machinery, generators, and engine room equipment, cargo handling and anchoring (e.g., thrusters, motor drivers, steering pumps, autopilots, fuel valves, and fire extinguishing systems) | Devices that can make something move or operate based on electronic signals (e.g. thrusters, motor drivers, steering pumps, autopilots, fuel valves, and fire extinguishing systems) |
| 4 | | **Shore Control Centres (SCC)** | SCC enables remote control and operations | SCC is site-remote entities from where monitoring and/or control of some or all ship functions can be executed. SCC is indispensable for MASS |
| 5 | | **Advanced Designs (AD)** | The following technologies enable AD:<br>- Modular engines designs<br>- Self-regulating, redundant, and fault-tolerant equipment<br>- Smaller and flexible hull designs to enable integration of sensors, docking and undocking and prevent piracy | New designs are required to take into account reduced onboard staffing, future changes in ship structures and equipment to enable the integration of various sensors, docking and undocking technologies and piracy countermeasures |
| 6 | | **System integrator** | System integrators enable the integration of all ships systems and subsystems:<br>- Cargo-handling/stowage<br>- Operational control, navigation technologies<br>- Remote and automated operation of machinery - Automated and remote maintenance and repair, and - Communication systems | System integrators integrate several components from various manufacturers to achieve a unified system. System and subsystem integration is indispensable for automation as subsystems integration is essential for safety and interoperability |
| 7 | **Communication technology** | **Internal communication links** | The following technologies enable internal communication links:<br>- Connectivity management system (software) (for integrated satellite-terrestrial systems)<br>- Wireless technologies including, Bluetooth, WALAN, WiFi, Wireless Mesh Networking (WMN), optical systems such as LiFi | Responsible for collecting data and information from sensors, monitors and other hardware to enable decision support systems and remote and autonomous decision-making, e.g. wireless technologies, including, Bluetooth, WALAN, WiFi, Wireless Mesh Networking (WMN) |

| | Main category Techs (Cluster 1) | Sub-category Techs (Cluster 2) | Examples of enabling/enabled technologies | Description (Cluster 2) |
|---|---|---|---|---|
| **8** | **Communication technology** | **Broadband that enables terrestrial communication links** | The following technologies enable terrestrial communication links:<br>- Long-Term Evolution (LTE) 5G, 6G<br>- WiFi and WIMAX<br>- Mobile wireless mesh and ad hoc networks (between shore and ships and between ships) | Use of terrestrial communication links that enable utilization of high bandwidths, which are essential for reliable connectivity between ship and shore (particularly in MASS) including infotainment, e.g. 5G, 6G, WiFi and WIMAX and mesh and ad hoc networks |
| **9** | | **Satellite and aerial communication** | The following technologies enable satellite communication links:<br>- Geostationary Satellite Orbit (GEO)<br>- Highly Elliptical Orbit (HEO)<br>- Middle and Low Earth Orbit (MEO/LEO)<br>- High-altitude platforms | Use of satellite to help the ship transfer and receive data and information with high bandwidth when there is no terrestrial links, e.g. geostationary satellite, high-altitude platforms |
| **10** | **Cybersecurity** | **Cybersecurity software and hardware** | Software and hardware technologies | Technologies, processes and practices that combine to protect networks, computers, programs, data and information from attack, damage or unauthorized access |
| **11** | **Digital and intelligent information technologies (digitalization)** | **Internet of Things (IoT)** | | Use of the Internet to interconnect sensing and monitoring devices (cargo, machinery, navigation, etc.), thus enabling the collection, sharing and exchange of data for processing internally and externally (ship-to-ship/ to-shore), which ultimately facilitates intelligent applications that enhance safety, route planning and optimization, collaborative decision-making, environmental monitoring, and energy-efficient operation |
| **12** | | **Big Data Platforms (BDP) & analytics, Cloud services (storage, IT services, edge computing)** | | BDP store and process data generated by sensors, devices and other objects, thus supporting in-depth analysis/ analytics (e.g. statistical analysis, data mining, market trends). It also expands data capacity and provides infrastructure to automate decision making |
| **13** | | **Blockchain** | | Blockchain authenticates and validates information transfer in a secure real-time way. It facilitates digital transformation through enabling trust, data integrity, traceability and transparency and smart contracts |
| **14** | | **Digital twinning** | | Analogue scale models (virtual replicas of physical items) that replicate actual physical assets with the added functionality of integrating processes, people, systems, and devices |

TABLE A1 List of future shipping technologies – Continued

| | Main category Techs (Cluster 1) | Sub-category Techs (Cluster 2) | Examples of enabling/enabled technologies | Description (Cluster 2) |
|---|---|---|---|---|
| 15 | **Digital and intelligent information technologies (digitalization)** | **3D and 4D printing** | | Additive manufacturing is an evolving technology for manufacturing layer-by-layer materials with complex geometry, e.g. non-linear holes and honeycombs that traditionally incur high production costs |
| 16 | | **Augmented Reality (AR) and Virtual Reality (AR)** | | VR creates a 3-D computer-generated environment that a user can explore and interact with. AR connects the real world with a virtual one with the aid of a device, where data from virtual system (e.g. a digital twin) are inserted precisely where necessary |
| 17 | **Robotics and drones** | **Robotics and drones** | Robotics and drones enable the following technologies:<br>Robots off board: e.g. sniffers that monitor ships emissions, Onboard robots: e.g. dispensers that do housekeeping tasks, Wearables: e.g. aiding crews to lift heavy items, firefighting, and maintenance tasks such as welding, cutting and fitting | Robot and drones can accomplish multifaceted and complicated tasks automatically with various capabilities, i.e. Cognition, versatility (flying, swimming, climbing), Imitation (human and animal actions), Senses (speaking, touching, listening), Adaptability (working in different environmental conditions, and wirelessly and battery driven) |
| 18 | **Advanced materials** | **Advanced materials** | Advanced materials:<br>- Microscale, nano-scale materials, composite materials, such as polymer matrix composites, and carbon fibre reinforced plastics<br>- Bio-inspired and bio-based materials | Advanced materials (e.g. metallic, ceramic, polymeric and composite materials) aim to deliver specific physical properties and improve capabilities, such as strength, toughness, and durability. Functional properties can also be improved, e.g. environmental sensing, self-cleaning, self-healing, enhanced electrical conductance and shape modification |
| 19 | **Sensors** | **Advanced sensors** | Advanced sensors:<br>- Semiconductors<br>- Micro-Electrical-Mechanical-Systems (MEMS)<br>- Remote sensing sensors | Use of robust and wireless sensors, such as the new generation of micro- and nano-mechanical sensors. Sensors are capable of remote sensing, embracing different characteristics (e.g. self-calibration, fault tolerance, high transmission capabilities, wireless capabilities, environmentally friendly materials for easy disposal) |
| 20 | **Low and zero-emission technologies** | **Alternative fuels** | Alternative fuels:<br>Biofuels, e.g. Hydro-treated Vegetable Oils (HVO), Fatty Acid Methyl Ester (FAME) and bio-ethanol, methanol, hydrogen and marine fuel cells, ammonia | Neutral and zero-carbon emission fuels, such as biofuels, bio-ethanol, methanol, hydrogen and marine fuel cells, ammonia |
| 21 | | **Electric propulsion systems and hybrids** | The following technologies enable electric propulsion and hybrids:<br>- Batteries<br>- Supercapacitors | Use of electric motors and generators. Batteries and supercapacitors are indispensable |

| | Main category Techs (Cluster 1) | Sub-category Techs (Cluster 2) | Examples of enabling/enabled technologies | Description (Cluster 2) |
|---|---|---|---|---|
| **22** | **Low and zero-emission technologies** | **Renewable energy** | The following technologies enable capture of renewable energy:<br>-Solar<br>-Wind | Use of sustainable energy, such as solar and wind to provide power |
| **23** | | **Exhaust treatment technologies** | - Methane catalyst reductor<br>- Carbon capture and storage | Technologies that treats $CO_2$ exhaust emission, such as the methane catalyst reductor and carbon capture and storage |
| **24** | | **Alternative fuel Bunkering** | | Shore-side bunkering infrastructure, particularly in ports, supply alternative fuels to calling ships |
| **25** | **Human-Computer Interaction (HCI)** | **Human-Computer Interaction** | | HCI technologies design the interface between human and computers. HCI enables human to interact with computers smartly so computers can recognize human requirements, commands, and preferences |
| **26** | **Human augmentation** | **Human augmentation** | | The technology aims at increasing human performance and cognitive capability far beyond typical levels. For example, in ships, lightweight modular exoskeleton devices could be used to increase the strength of crew members in some operations, such as carrying heavy loads, thereby reducing fatigue and injuries |

TABLE A2 List of top-30 trends as a result of the expert survey*

| STEEP | Trends |
|---|---|
| **Economic** | **Expanding role of the green and blue economy** |
| | **Rise of new business models and ecosystems driven by technology** |
| | **Increasing e-commerce and digital consumption** |
| | Increasing importance of Asia and emerging economies as economic powers |
| | Rise of new innovative companies on the market |
| **Environmental** | **Expanding the green economy** |
| | Increased severe consequences of climate change |
| | Increasing concerns about ocean health |
| | Increased pressure on ecosystems (resource stress) |
| | Growing scarcity of resources |
| **Political** | Rising concerns about security (including cybersecurity, synthetic media, terrorism and war) |
| | **Increased geopolitical volatility** |
| | **Increasing role of technology regulation and governance** |
| | Rise of populism, nationalism and alternative governance systems |
| | Increased regionalization of the future (localized global supply chains) |
| | Decline in globalization and increased reshoring/ nearshoring of business processes to developed countries |
| | Increasing role of globalization and interconnected economies |
| **Societal** | Expanding importance of climate sustainability and green targets |
| | Changing nature of work due to technology (unbounded work, flexible work, digitalized workplace and HR practices) |
| | Increased ageing of populations and generational differences |
| | Expanding importance of social sustainability, equality and diversity |
| | **Widening economic and skills inequalities** |
| | Increasing access to online education** |
| | Rise of deskilling |
| **Technological** | Shift to greener technologies |
| | Accelerating digitalization, dematerialization and hyperconnectivity |
| | **Increasing use of smart ships** |
| | **Increasing concerns and solutions for cybersecurity and digital transparency** |
| | **Rising importance of autonomous ships** |
| | Increasing the importance of Shore Control Centres (SCC) |

*Top-10 trends that have been selected by the maritime stakeholders in the workshops are in Bold

# ANNEX B

TABLE B1 List of training courses offered by technology providers

| Course conducting firm | Subject | Target group | Learning Objective |
|---|---|---|---|
| **ABB Marine Academy[a] (Switzerland/ Sweden)** | LNG Electrical propulsion system | Marine engineers and electro-technical personnel | • Understand the function of the electrical propulsion control system.<br>• Operate the maintenance station. |
| | Drilling drive system, advanced | Marine engineers and electro-technical personnel | • Explain the project configuration and function of different components.<br>• Trace alarms from the process panel down to drives and control components.<br>• Discuss system backup and recovery. |
| | Cycloconverter system | Electricians, technicians and engineers | • Describe the drive system components.<br>• Explain the basic operation principle.<br>• Identify drive components and configure settings.<br>• Operate the drive.<br>• Carry out preventive maintenance.<br>• Perform basic troubleshooting tasks.<br>• Locate and replace faulty hardware components. |
| | Azipod technical training | Marine engineers and electro-technical personnel | • Have advanced knowledge of Azipod system.<br>• Understand the functioning of the propulsion and drive control.<br>• Operate and maintain Azipod drive system.<br>• Perform basic troubleshooting of the system. |
| | Azipod vessel operation, operational level | Azipod vessel deck personnel at operational level | • Be familiar with the operational principles of diesel-electric Azipod systems.<br>• Understand the flexibility of the system.<br>• Identify potential malfunctions and to cope with them without sacrificing vessel safety. |
| | Azipod vessel operation, management level | Azipod vessel deck personnel at management level | • Have deep understanding of the operational principles of diesel- electric Azipod vessels taking into account vessel safety, passenger comfort, operational efficiency and maintenance needs.<br>• Fully utilize the flexibility of the propulsion system.<br>• Identify potential malfunctions and to cope with them without sacrificing vessel safety. |
| | Advanced automation training for operators | Marine engineers and electro-technical personnel | • Understand all process alarms and events.<br>• Use alarms as fault tracing.<br>• Optimize equipment use in normal operation.<br>• Understand and control the automation processes |
| | Advanced automation training for maintenance | Marine, O&G, Operators, Engineers and Superintendents Electro-technical personnel | • Understand the philosophy of Advant/Master system.<br>• Fully use engineering functionalities, in order to maximize productivity.<br>• Troubleshoot common issues.<br>• Reduce decision time.<br>• Perform engineering activities for runtime operations and optimize the process. |
| | DEGO (Diesel Engine Governor) electronic governor systems | Marine engineers and electro-technical personnel | • Understand and identify abnormal behaviour of the DEGO systems.<br>• Locate faults in the different units.<br>• Repair by replacement.<br>• Perform calibrations and make fine tunings.<br>• Perform basic maintenance and repairs on related actuators. |
| | Azipod space safety | All deck, engine and electro-technical personnel | • Identify the different hazards risks and the possible consequences when working inside the Azipod unit´s space.<br>• Enter and work safely inside the Azipod unit space.<br>• Understand the duties of confined space personnel (Entrant, Attendant, Supervisor and Rescuer).<br>• Attend an Entrant during normal entry.<br>• Assist during an emergency. |

[a] ABB Marine Academy website: https://new.abb.com/marine/systems-and-solutions/service/training

TABLE B1 List of training courses offered by technology providers – Continued

| Course conducting firm | Subject | Target group | Learning Objective |
|---|---|---|---|
| **ABB Marine Academy[b] (Switzerland/ Sweden)** | OCTOPUS Onboard Basic | ship officers, project engineers and cargo superintendents | • Explain the OCTOPUS system architecture and identify the functions of its components<br>• Configure virtual points for measurement<br>• Design graphs for outputting the required data in real time<br>• Understand the basics of vessel motions, velocities and accelerations<br>• Maximize the quality of input data for the system<br>• Accurately translate the system output into clear advices<br>• Implement and understand criterions<br>• Troubleshoot most common basic problems |
| **WÄRTSILÄ Academy[c] (Finland)** | NOx Reducer (NOR) Operation | Marine and electrical engineers | • Legislation and regulations overview<br>• Work safety<br>• Design and function of the system and its components<br>• Operating conditions and limitations<br>• Chemical requirements<br>• Service and maintenance |
| | SOx Scrubber Operation | Marine and electrical engineers | • Legislation and regulations overview<br>• Work safety<br>• Design and function of the system and its components<br>• Operating conditions and limitations<br>• Chemical requirements<br>• Service and maintenance |
| | LNGPAC Operation Advanced | All ship's crew working on board ships powered by liquefied gas | • Gas properties and safety<br>• Environmental legislation<br>• Dual Fuel engine technology<br>• Design and function of LNGPac<br>• Start, stop and operation of LNGPac<br>• Control and Automation of LNGPac<br>• Maintenance of LNGPac |
| | UV (Ultra Violet) & EC (Electro Chlorination) Ballast Water Management System | Marine engineers and electricians | • IMO and USCG legislations<br>• Safety instructions for working with Ultra Violet radiation<br>• Safety instructions for working with an Electro Chlorination system<br>• Design and function of the Ballast Water Management System<br>• Operation, service and maintenance<br>• Hands on operation, service and maintenance of the Ballast Water Management System |
| | Marine Gas Safety | All ship's crew working on board ships powered by liquefied gas | • Requirement and Treatment of Fuel Gas<br>• General Health and Safety Aspects of Gas and LNG<br>• General rules and procedures<br>• General design of Wärtsilä LNGPac<br>• Safety and protection systems<br>• LNGPac Operation principles |
| | Vessel Automation, IAS & PMS, Power Distribution And Variable Speed Drives | Marine engineers and electricians | • Integrated Automation System (IAS): Principles and Features<br>• Power Management System (PMS): Principles and Features<br>• Power Distribution: Principles and Features<br>• Variable Speed Drive (VSD): Principles and Features<br>• Hands-on (on board only) |
| | Automation HV - Power and Propulsion | Electro technical engineers | • High Voltage Power and Propulsion System<br>• Main Propulsion System<br>• Thruster Drive System<br>• Operation of each sub component |
| | ECDIS - Type Specific | Deck officers, Nautical inspectors, and Authorities e.g. Port State Control | • EDCIS definition and legal status<br>• ECDIS vocabulary<br>• Chart-Maintenance<br>• ECDIS Monitoring<br>• ECDIS Planning |

[b] ABB Marine Academy website: https://new.abb.com/marine/systems-and-solutions/service/training

[c] WÄRTSILÄ LAND & SEA ACADEMY TRAINING PROGRAMME CATALOGUE: https://www.wartsila.com/wlsa

TABLE B1 List of training courses offered by technology providers – Continued

| Course conducting firm | Subject | Target group | Learning Objective |
|---|---|---|---|
| **WÄRTSILÄ Academy**[d] **(Finland)** | Integrated Navigation System | Deck officers, Nautical inspectors, and Authorities e.g. Port State Control | • Definition of IBS/INS<br>• Principle task of IBS/INS<br>• Integration of tasks in workstations<br>• Familiarization with SAM - INS components<br>• Use of IBS/INS in exercises<br>• Radar pilot principle and practical use<br>• the practical use of Track pilot<br>• the practical use of Speed pilot |
| **Kongsberg Maritime**[e] **(Norway)** | Different version of AUTOCHIEF | Marine and electrical engineers | • Knowledge of propulsion Control System including complete control and safety system suitable for all two and four stroke engines, both fixed and controllable pitch propellers |
| | Different version of K-CHIEF | All deck and engineer officers | • Knowledge of distributed monitoring and control system including: Power management, auxiliary machinery control, ballast/ bunker monitoring and control and cargo monitoring and control. |
| | K-BRIDGE Operator Course Including ECDIS Familiarization | Deck officers | • Knowledge of Integrated Navigation System and ECDIS |
| | Different type of Azimuth thruster | Marine and electrical engineers | • Knowledge of operation and maintenance of Azimuth thrusters<br>• Fully utilize the flexibility of the propulsion system.<br>• Identify potential malfunctions and to cope with them without sacrificing vessel safety. |
| | K-MASTER for operators and maintenance | Deck officers and electrical engineers | • Skill of operations from the K-Master control chair<br>• Knowledge of periodic maintenance of the K-Master system |
| **Rolls-Royce**[f] **(United Kingdom)** | Acon, automation system | All deck and engineer officers | • Knowledge about the Acon system including: Bridge and ECR operation stations components, alarm panels, tank sounding system, and remote switchboard operation.<br>• Knowledge about the Acon system operation, the different alarm situations and the effect that they may have on the vessel performance.<br>• Knowledge about the possibilities and limitations of the system and how to reduce human errors and their effects. |
| | Acon LNG, automation system | All deck and engineer officers | • Similar to above |
| | Azipull manoeuvring with Helicon controls | Deck officers | • Ability to manoeuvre a vessel with Azipull or Azimuth thrusters as a propulsion system and understand the design and basic functionality of the Helicon control system. |
| | Podded propulsor, Mermaid pod (Maneuvering training) | Deck officers | • Knowledge of pod propulsion system and its remote-control system and manoeuvring capabilities<br>• Operation in back-up mode and from ECR and pod room |
| | Power electric propulsion system | Marine and electrical engineers | • Knowledge about operation of the main switchboard, blackout prevention system, power management system and the AFE frequency converter drive. |
| | Waterjet, different series of Kamewa | Marine and electrical engineers | • Deep understanding of the design and function of the Rolls-Royce waterjet<br>• Knowledge of preventive maintenance to promote the reliable and efficient operation of waterjet system. |

[d] WÄRTSILÄ LAND & SEA ACADEMY TRAINING PROGRAMME CATALOGUE: https://www.wartsila.com/wlsa

[e] Kongsberg Maritime Course Catalogue: https://training.km.kongsberg.com/course-categories

[f] Rolls-Royce Marine product training course catalogue: https://www.rolls-royce.com/~/media/Files/R/Rolls-Royce/documents/customers/marine/marine-product-training.pdf

TABLE B1 List of training courses offered by technology providers – Continued

| Course conducting firm | Subject | Target group | Learning Objective |
|---|---|---|---|
| **SIEMENS Energy Offshore Marine Center[g] (Germany)** | Technical training BlueDrive PlusC | Marine and electrical engineers | • Introduction of Bluedrive PlusC diesel-electric marine solutions roadmap and architecture, focusing on the interplay of different system modules to optimize vessel operations.<br>• Discussion about technical solutions for load sharing, blackout prevention and recovery. |
| | Technical training BlueVaul energy storage solutions | Marine and electrical engineers | • The course provides basic knowledge of the structure and functions of BlueVault (Energy Storage Solution), covering different applications, operational principles and safety. |
| **Yara Marine Training Academy[h] (Norway)** | SOx Scrubber System | Electrical and engine officers, technical staff and superintendents | • Understand the working principles and operational functions of the Yara Marine SOx scrubber<br>• Increased safety and equipment reliability<br>• Reduced operating and maintenance costs<br>• Understanding about the regulations and documents controlling the system operation, as well as compliance with regulatory requirements |
| **Alfa Laval[i] (Sweden)** | PureBallast | Electrical and engine officers, and superintendents | • Principles of ballast water treatment and the differences between ballast water treatment technologies<br>• Practical identification of PureBallast system components and their function<br>• PureBallast operation and processes<br>• Practical simulation of different operational conditions<br>• Practical maintenance and calibration of PureBallast |
| | PureSOx | Electrical and engine officers, and superintendents | • PureSOx basics and how the system works<br>• System components and their function<br>• Alarms and warnings<br>• Tracing and resolving common system failures<br>• Non-compliance scenarios and their causes<br>• Maintenance schedules, scope and procedures |

[g] SIEMENS offshore and marine training course brochure: https://assets.new.siemens.com/siemens/assets/api/uuid:d7368ffd-82e9-45ec-b9ee-c094b99f7e62/marinetraining-courses.pdf

[h] Yara Marine Training Academy brochure: https://yaramarine.com/app/uploads/2020/05/Yara-Marine-Academy.pdf

[i] Alfa Laval website: https://www.alfalaval.com/service-and-support/service-overview/support-services/training/marine-training/

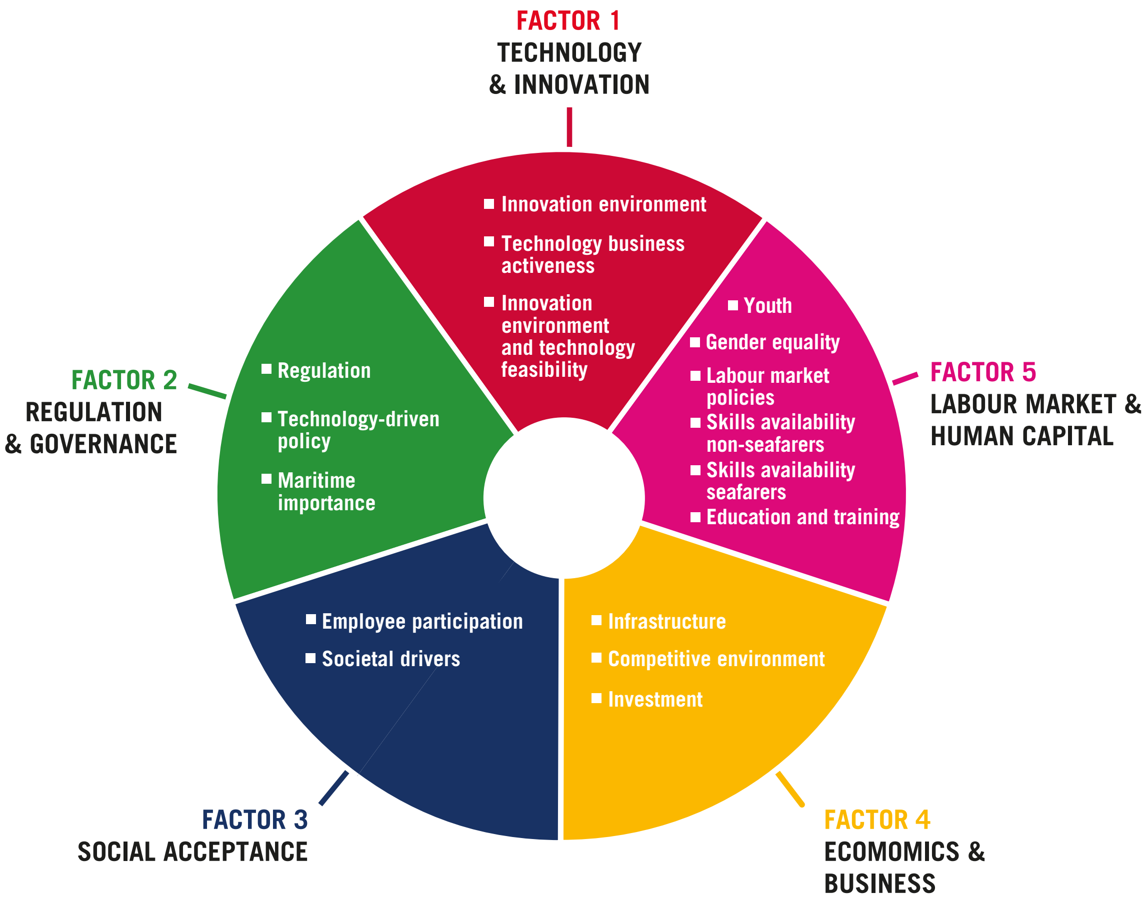
Annex C

# ANNEX C

TABLE C1 List of operational software and providing companies

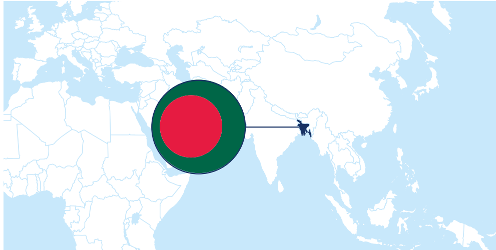
| Company | Product | Coverage | | | | | | | | | | Country |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Data Collection System | Vessel Performance Monitoring | Speed Optimization | Trim Optimization | Weather Routing | Hull & Propeller Performance Monitoring | Engine Monitoring | Alarm & Monitoring System | Power Management System | Loading/ stability Software | |
| ZERONORTH | Optimize | | X | X | | | | | | | | Denmark |
| Nautilus | Fleet Dashboard | | X | X | | | | | | | | USA |
| StormGeo | s-Suite | | X | X | | X | | | | | | Norway |
| Marine Digital | Fuel Optimization System (FOS) | X | X | X | | X | X | | | | | Germany |
| METIS | METIS ship connect | X | X | | | | | X | | | | Greece |
| Trelleborg | Ship Performance Monitoring (SPM) | X | X | | X | | | | | | | UAE |
| COACH Solutions | COACH Vessel Performance | X | X | X | | X | X | X | | | | Denmark |
| Force Technology | SeaSuite | X | X | X | X | | X | X | | | | Denmark |
| Kyma | • Ship Performance<br>• Delfini<br>• Diesel Analyser | X | | | X | | X | X | | | | Norway |
| LEAN MARINE | • Fuel Opt<br>• Fleet Analytics | X | X | | | | | X | | | | Sweden |
| ULSTEIN | • Power solutions<br>• Automation solutions | X | | | | | | | X | X | | Norway/ Netherland |
| NAPA | • Loading/emergency computer<br>• NAPA Logbook<br>• NAPA Voyage Optimization<br>• NAPA Fleet Intelligence | X | X | X | | X | X | | | | X | Finland |
| CETENA | • Performance Monitoring (PM)<br>• Optimum Trim Estimator (OTE)<br>• Hull Monitoring System (HMS) | X | X | | X | | | | | | X | Italy |
| Høglund Marine Solutions | Ship Performance Monitor (SPM) | X | X | X | | | | | X | X | | Norway |
| MARORKA | Marorka Onboard/Online | X | X | X | X | X | X | X | | X | | Iceland |
| MACSEA | • HULL MEDIC<br>• DEXTER suite<br>• Fuel vision | X | X | | | | X | X | X | | | USA |
| M.A.C. System Solutions | PMSnet / SDBnet | X | X | | | | | | | | | Germany |
| SkySails | Vessel Performance Manager (V-PER) | X | X | X | X | X | X | X | | | | Germany |
| Propulsion Dynamics | Computerized Analysis of Ship PERformance (CASPER) | X | X | X | X | | X | | | | | Denmark/ USA |
| GreenSteam | Discover | | | X | X | | X | | | | | Denmark |
| ABB | • Octopus<br>• EMMA Suite<br>• Power and Energy Management System (PEMS) | X | X | X | X | X | X | X | X | X | | Switzerland/ Sweden |
| Kongsberg | Ship Performance System (SPS) | X | X | X | X | X | X | X | X | X | X | Norway |
| Wärtsilä | • Navi-Planner<br>• Smart Voyage | X | X | X | X | X | X | X | X | X | | Finland |
| Yara marine | • FuelOpt | X | X | X | | | | X | | | | Norway |

# ANNEX D
# DETAILED MARITIME COUNTRY PROFILES



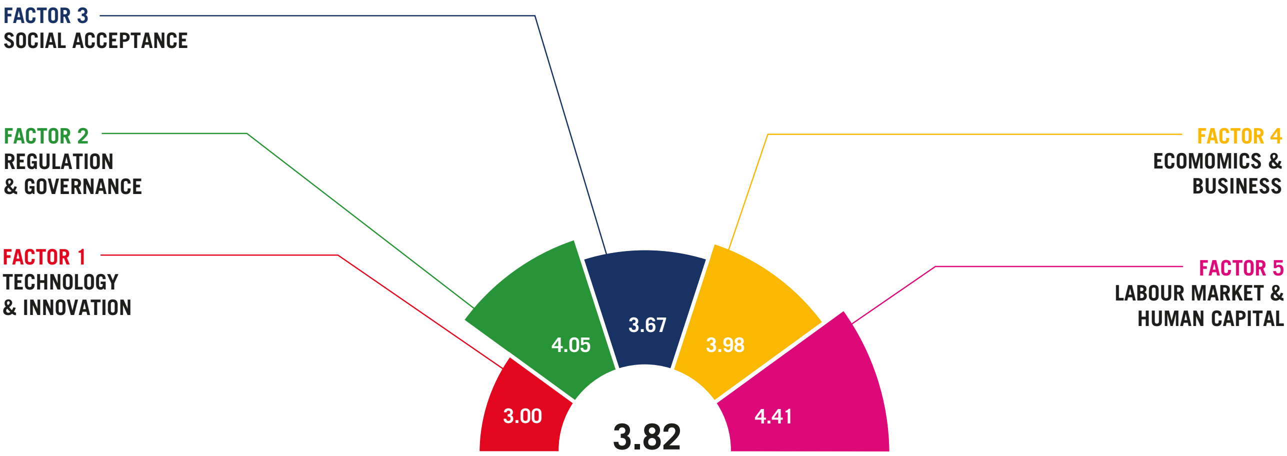

Sources
UNCTAD Handbook of Statistics 2022
The World Bank - Web site - 2021
https://data.worldbank.org

# BANGLADESH



POPULATION (2021-2022)
**169 MILLION**

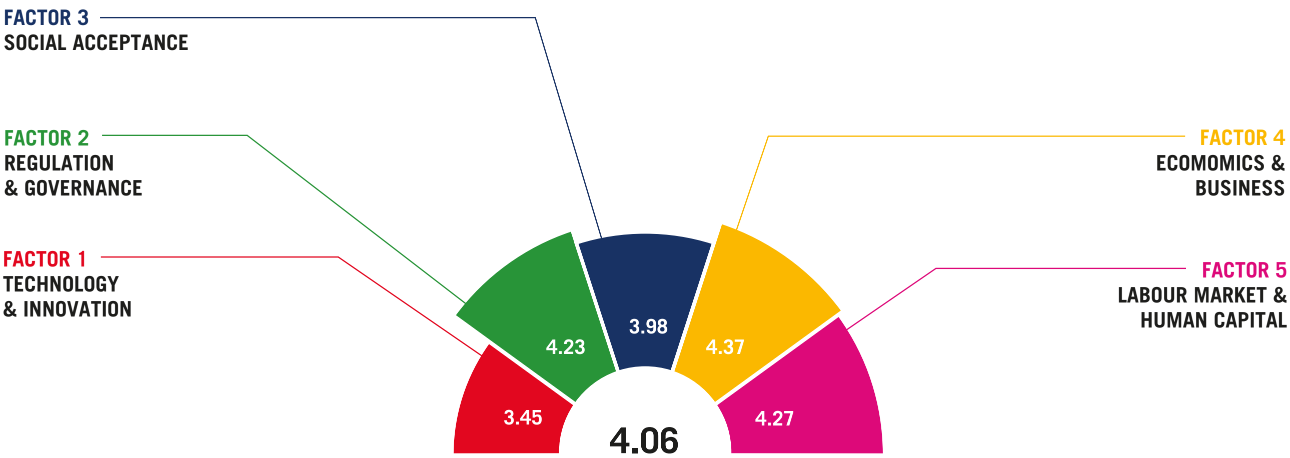
GDP US$ (2021)
**416,265 MILLION**



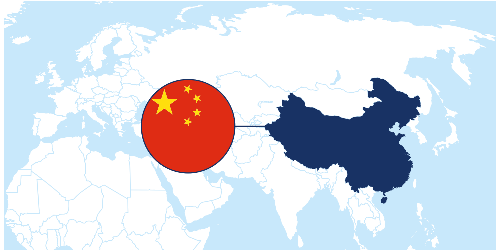

# CHILE

POPULATION (2021-2022)
**19 MILLION**

GDP US$ (2021)
**317,059 MILLION**

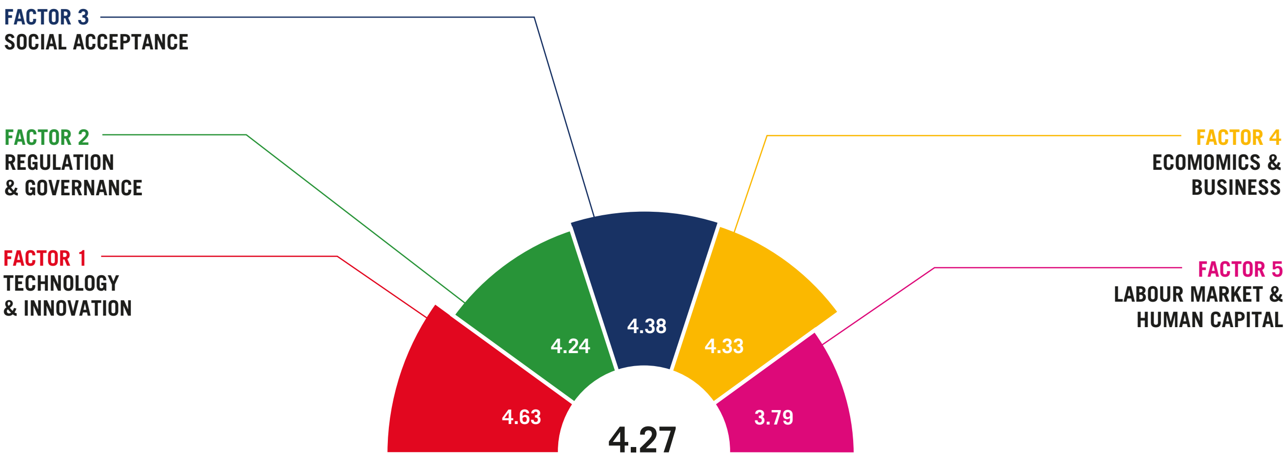


# CHINA



**POPULATION (2021-2022)**
1426 MILLION

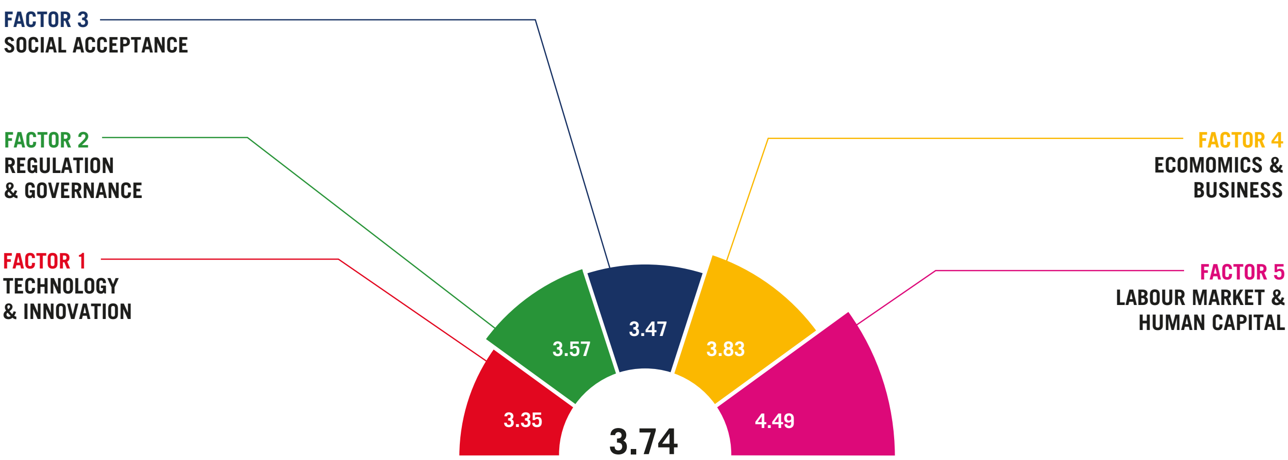
**GDP US$ (2021)**
17,734,063 MILLION




# EGYPT

**POPULATION (2021-2022)**
109 MILLION

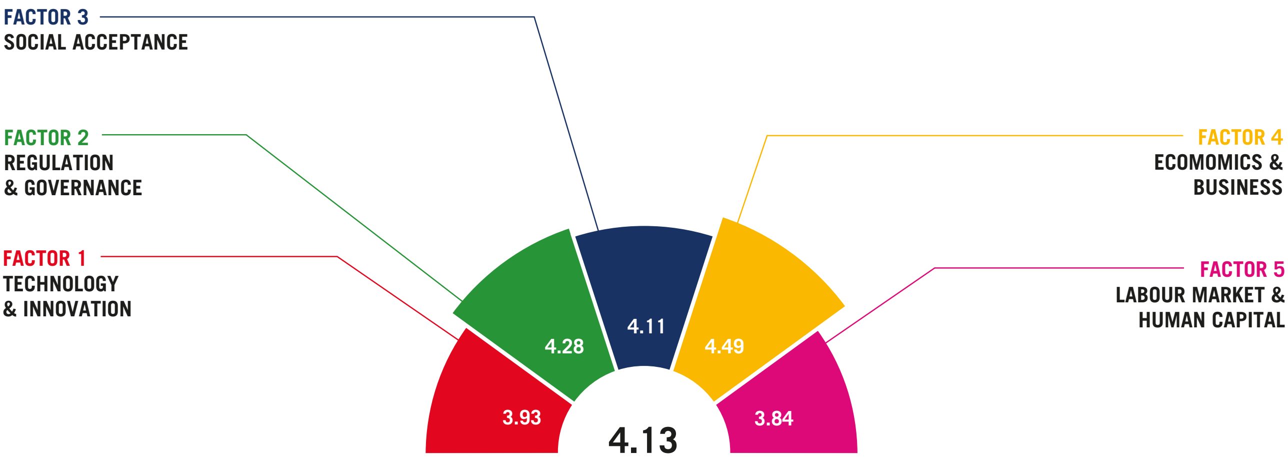
**GDP US$ (2021)**
404,143 MILLION



# GERMANY

POPULATION (2021-2022)
**83 MILLION**

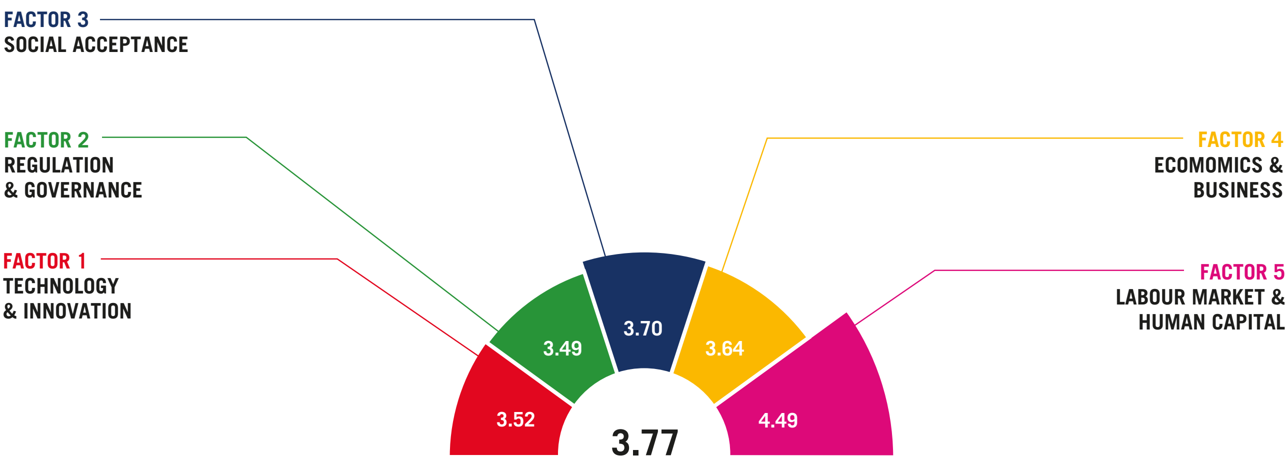
GDP US$ (2021)
**4,259,935 MILLION**



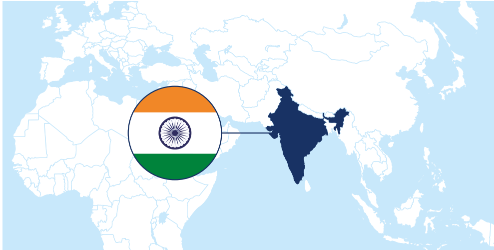

# GHANA

POPULATION (2021-2022)
**32 MILLION**

GDP US$ (2021)
**77,594 MILLION**

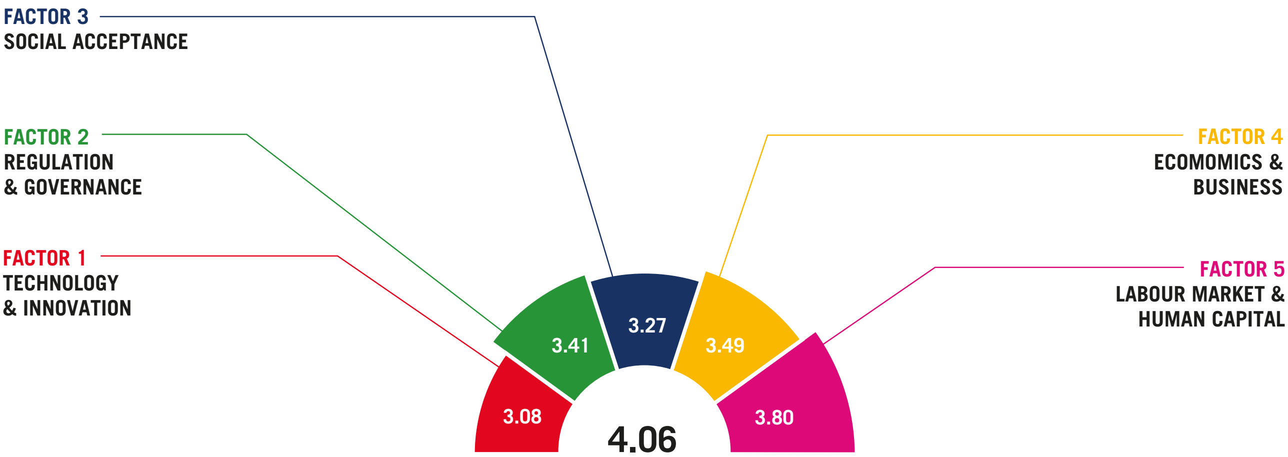


# INDIA



**POPULATION (2021-2022)**
**1408 MILLION**

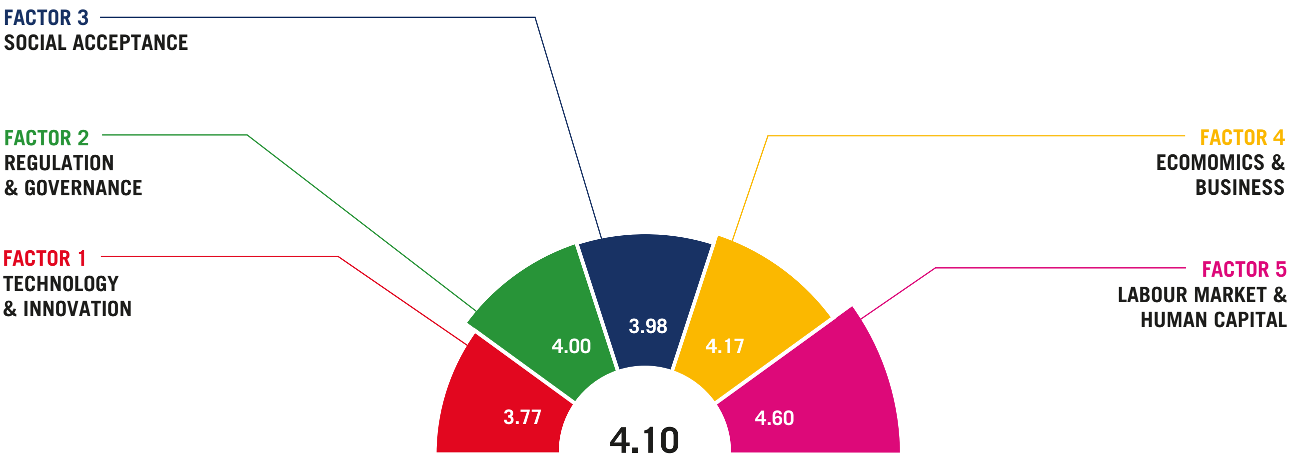
**GDP US$ (2021)**
**3,176,295 MILLION**



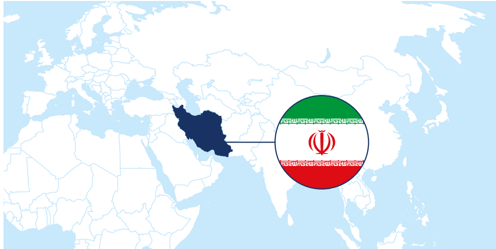

# INDONESIA

**POPULATION (2021-2022)**
**274 MILLION**

**GDP US$ (2021)**
**1,186,093 MILLION**

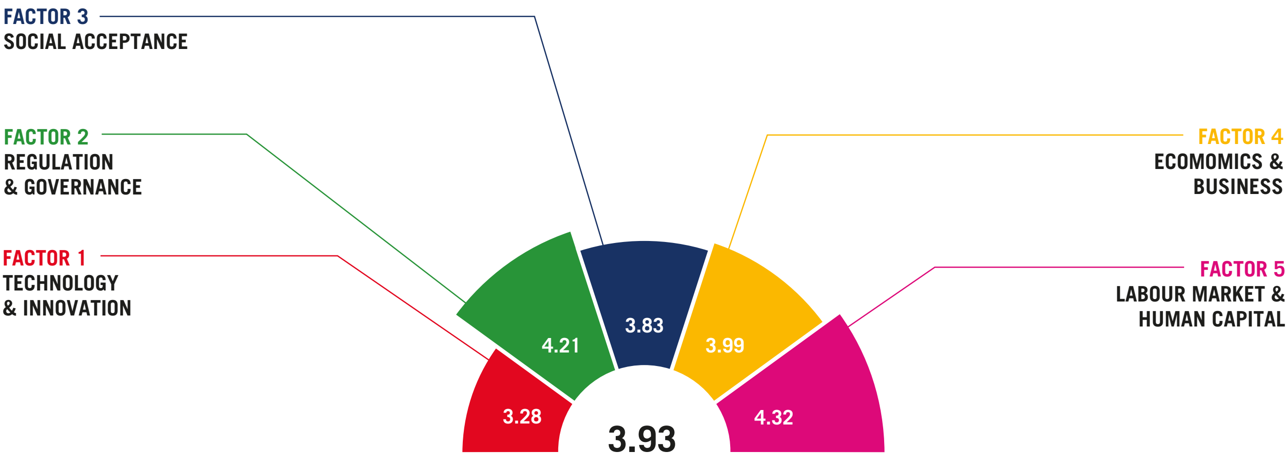


# IRAN (ISLAMIC REPUBLIC OF)

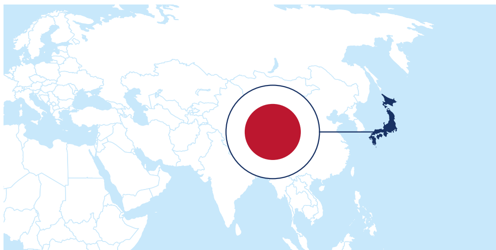


POPULATION (2021-2022)
**85 MILLION**

GDP US$ (2021)
**359,713 MILLION**

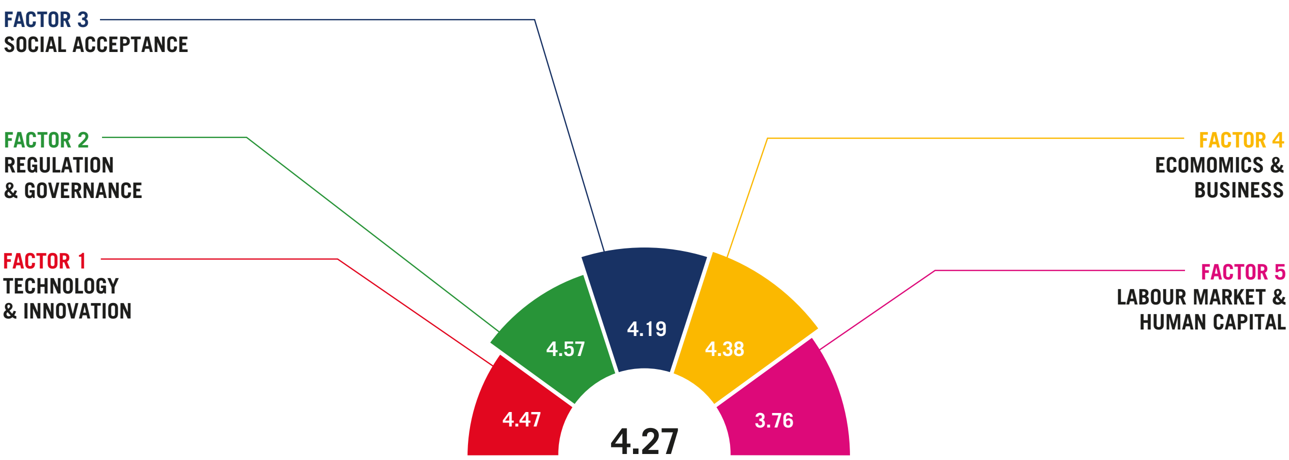



# JAPAN

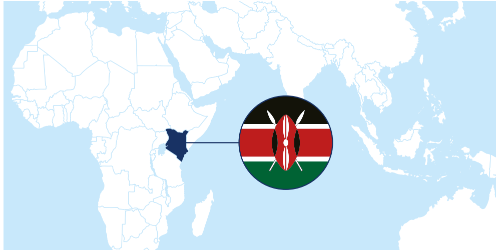


POPULATION (2021-2022)
**125 MILLION**

GDP US$ (2021)
**4,940,878 MILLION**

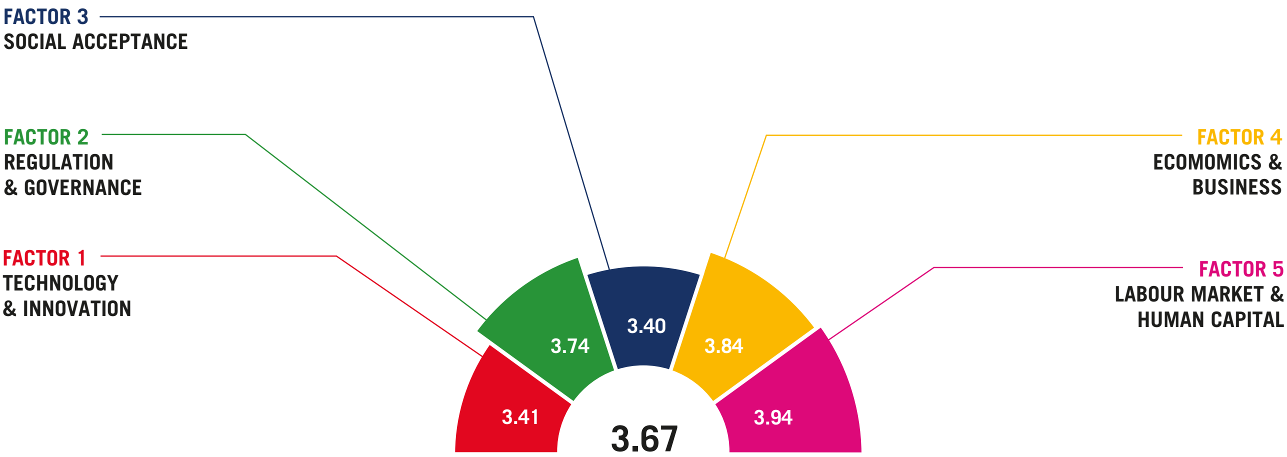


# KENYA

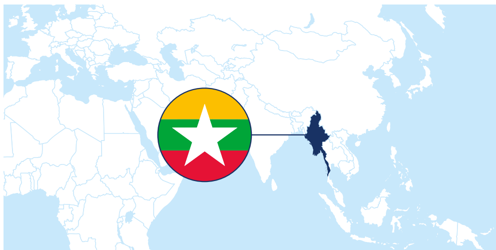


POPULATION (2021-2022)
53 MILLION

GDP US$ (2021)
110,347 MILLION

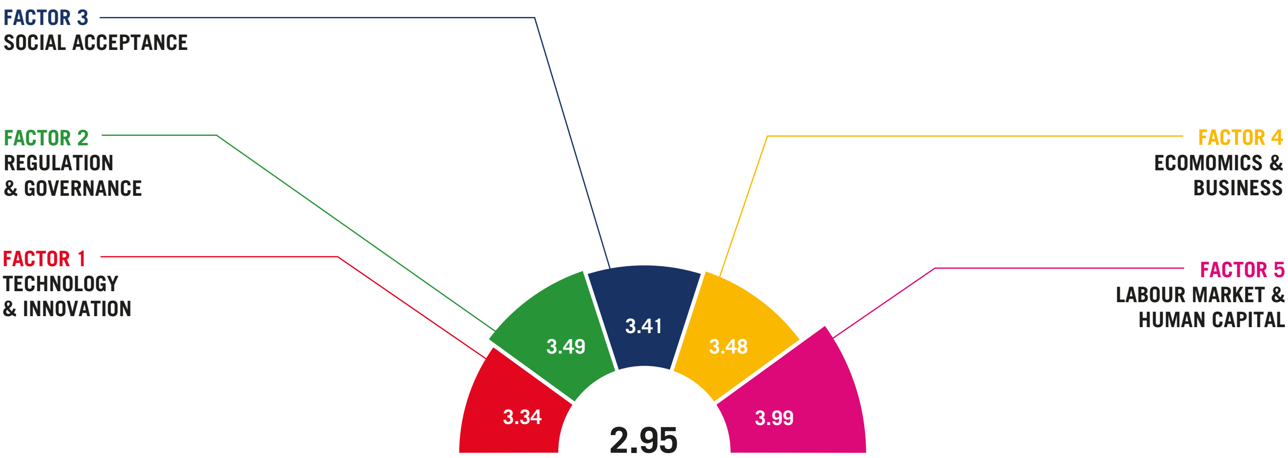



# MYANMAR

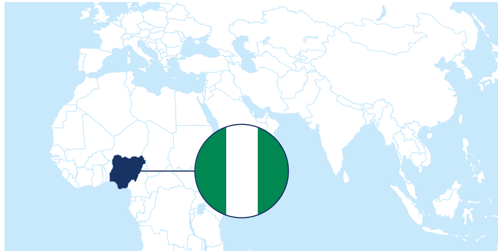


POPULATION (2021-2022)
54 MILLION

GDP US$ (2021)
65,092 MILLION

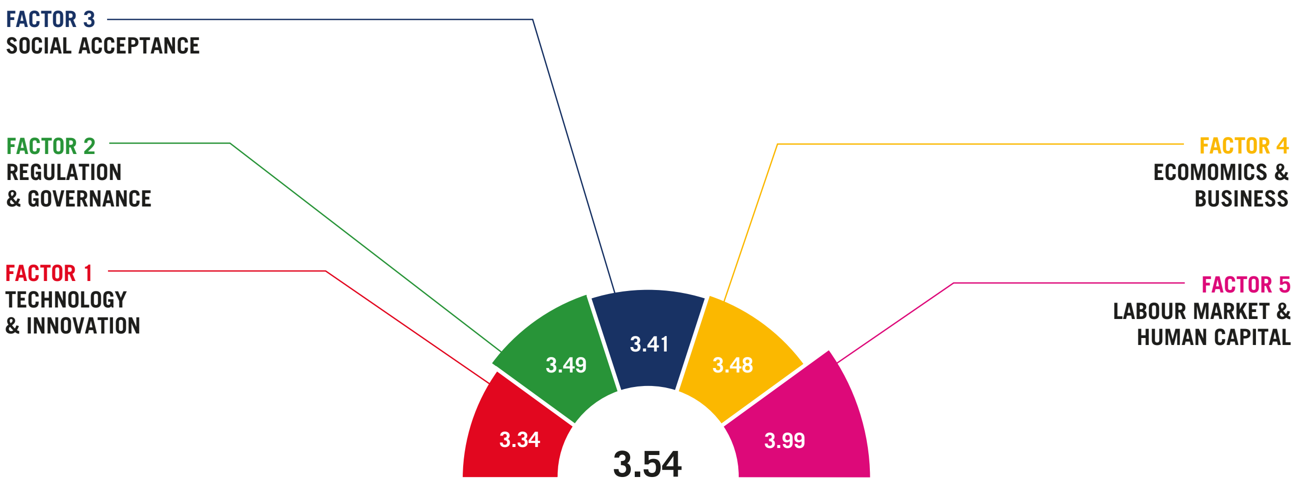


# NIGERIA

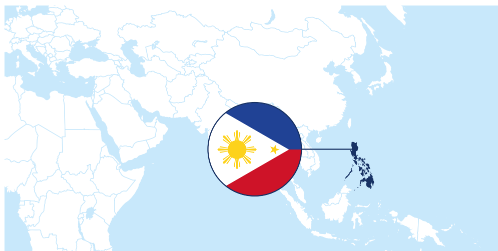


**POPULATION (2021-2022)**
**213 MILLION**

**GDP US$ (2021)**
**440,834 MILLION**

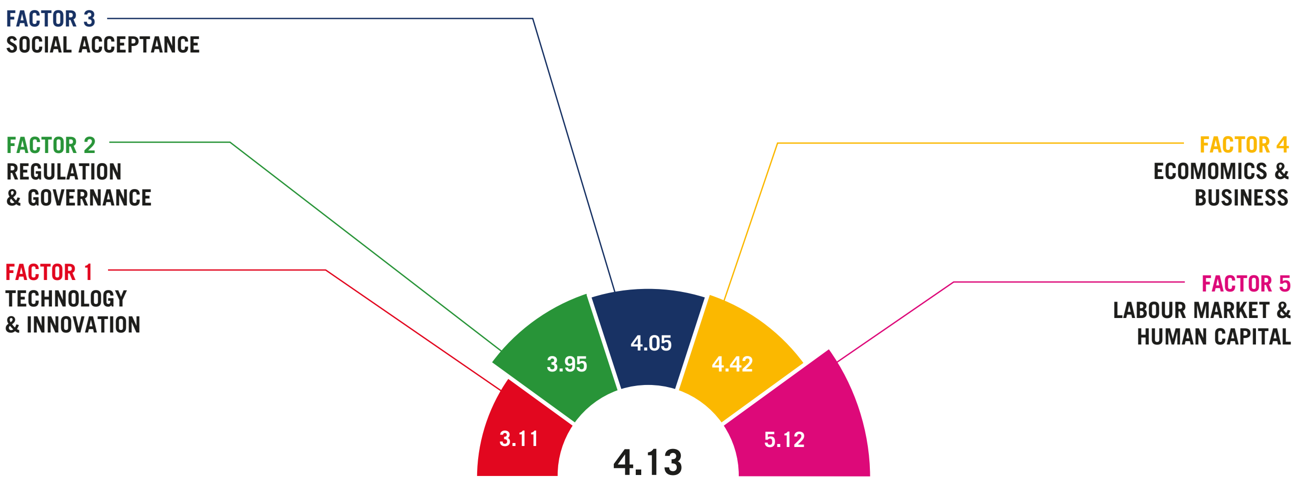



# PHILIPPINES

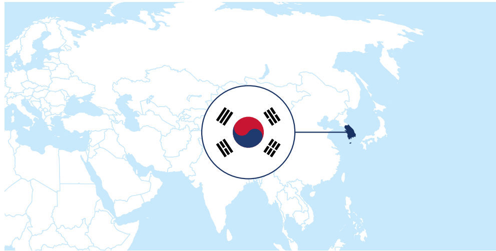


**POPULATION (2021-2022)**
**114 MILLION**

**GDP US$ (2021)**
**394,086 MILLION**

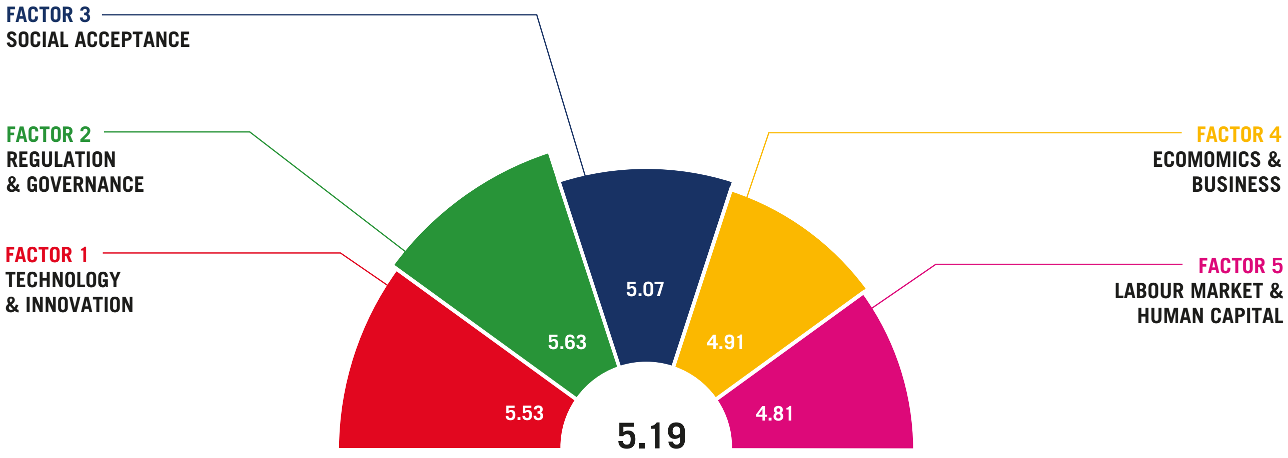


# REPUBLIC OF KOREA

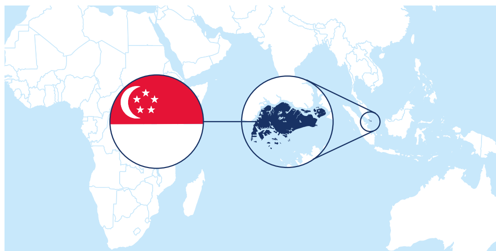


**POPULATION (2021-2022)**
51 MILLION

**GDP US$ (2021)**
1,810,956 MILLION

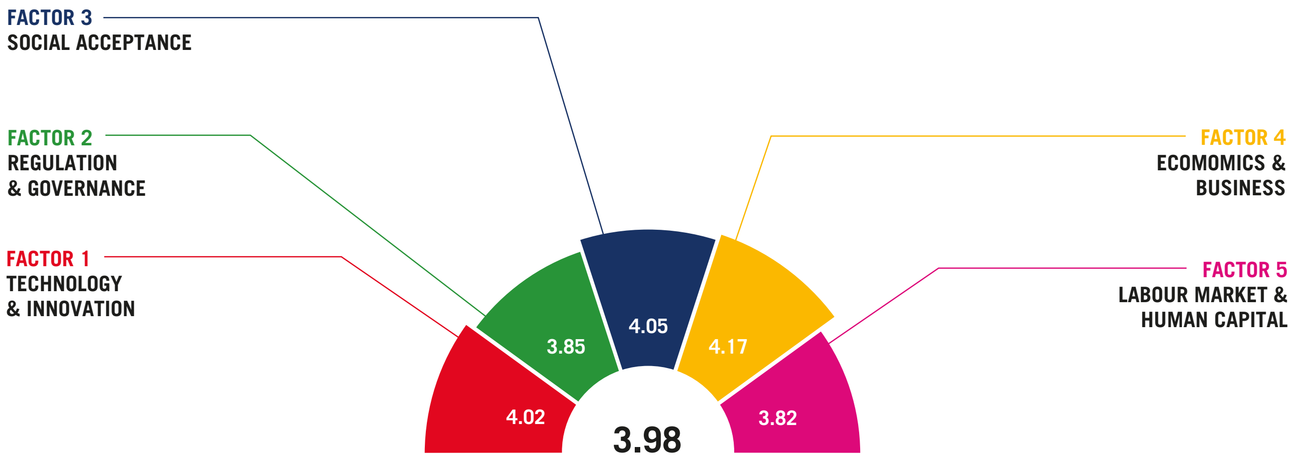



# SINGAPORE



**POPULATION (2021-2022)**
5 MILLION

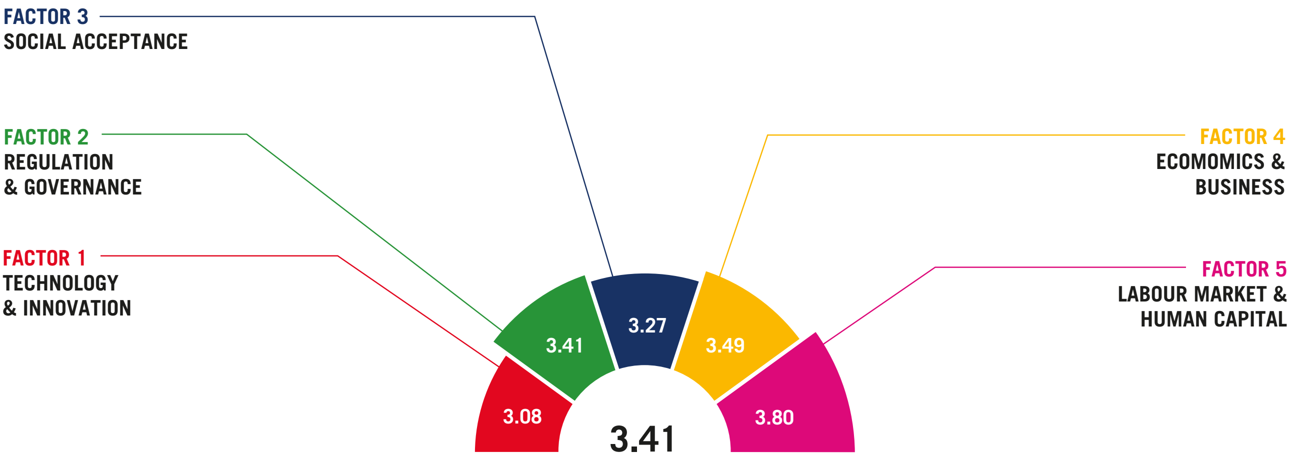
**GDP US$ (2021)**
396,987 MILLION



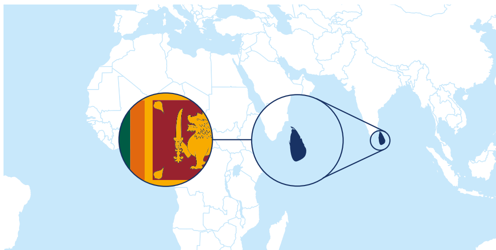
# SOUTH AFRICA

**POPULATION (2021-2022)**
**59 MILLION**

**GDP US$ (2021)**
**419,015 MILLION**

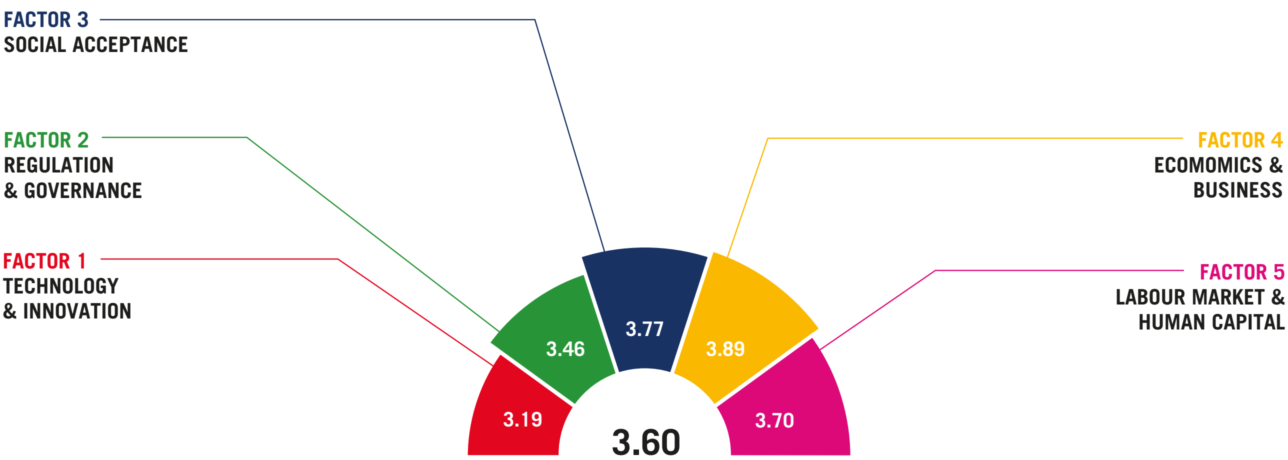



# SRI LANKA

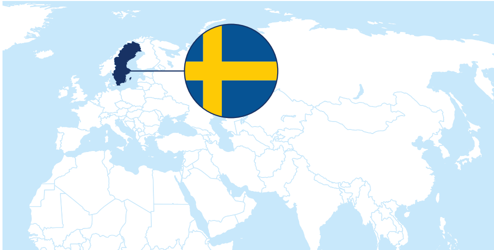


**POPULATION (2021-2022)**
**22 MILLION**

**GDP US$ (2021)**
**88,927 MILLION**

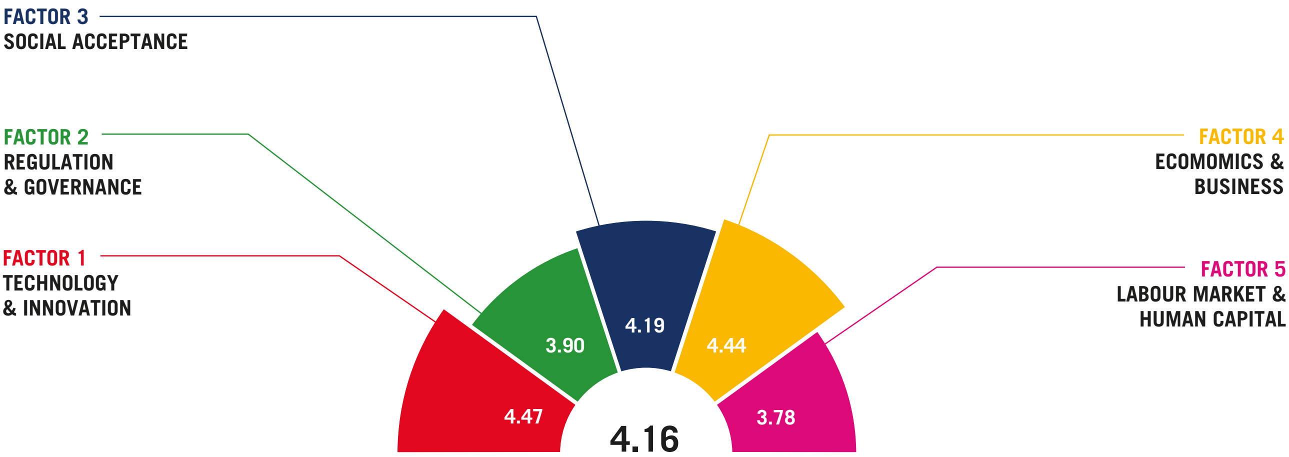


# SWEDEN

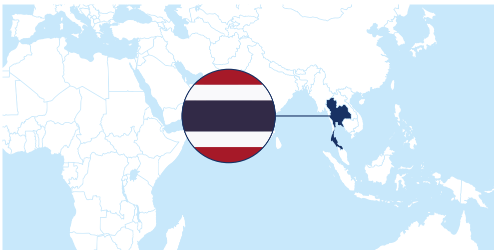


POPULATION (2021-2022)
10 MILLION

GDP US$ (2021)
635,664 MILLION

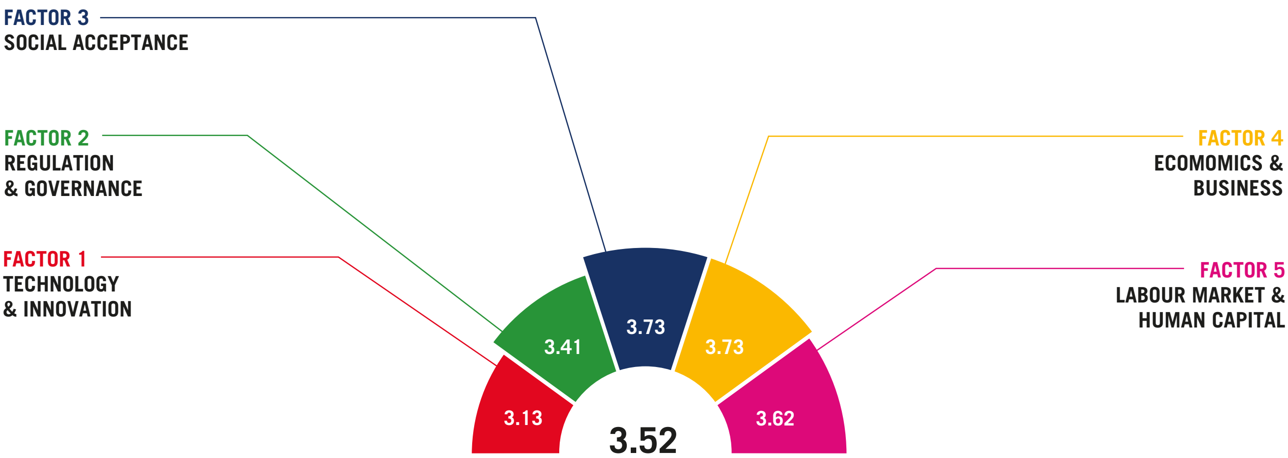



# THAILAND



POPULATION (2021-2022)
72 MILLION

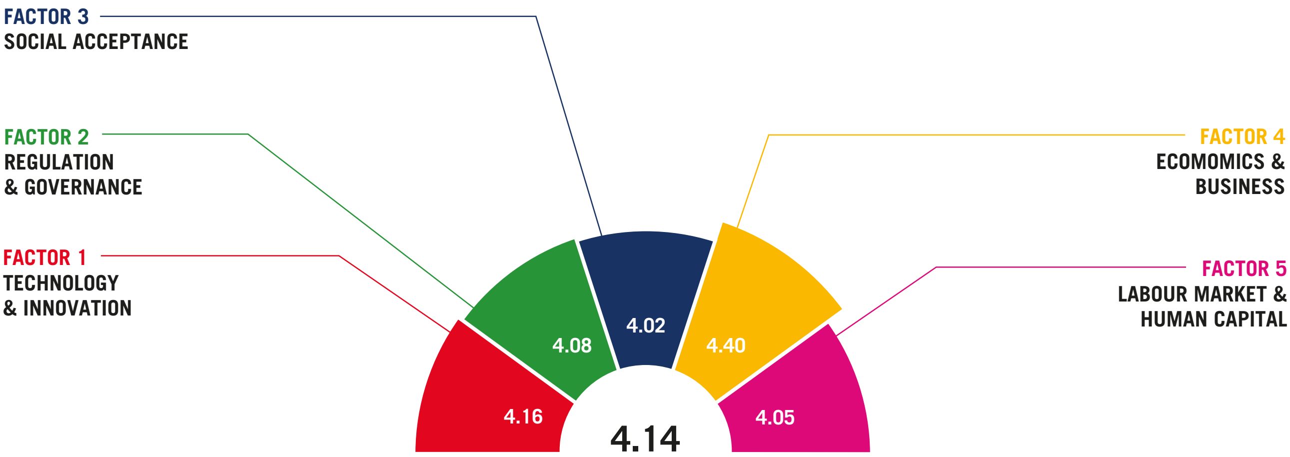
GDP US$ (2021)
505,947 MILLION



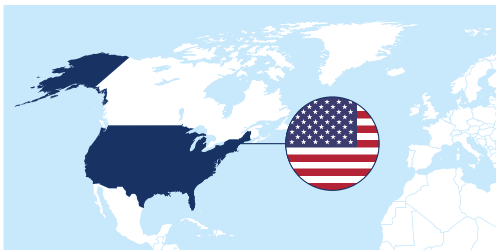
# UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND

**POPULATION (2021-2022)**
61 MILLION

**GDP US$ (2021)**
3,131,378 MILLION

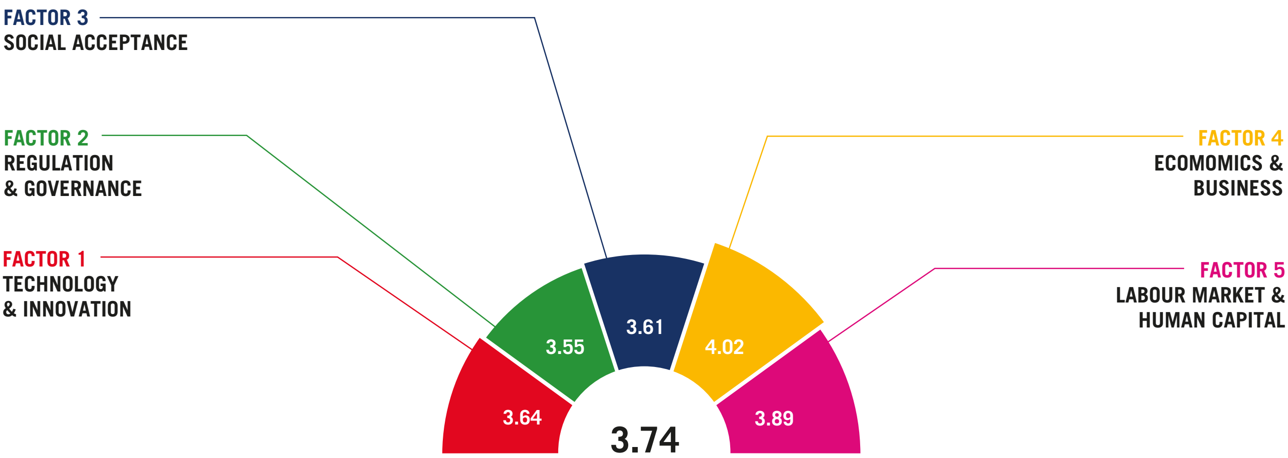



# UNITED STATES OF AMERICA



**POPULATION (2021-2022)**
340 MILLION

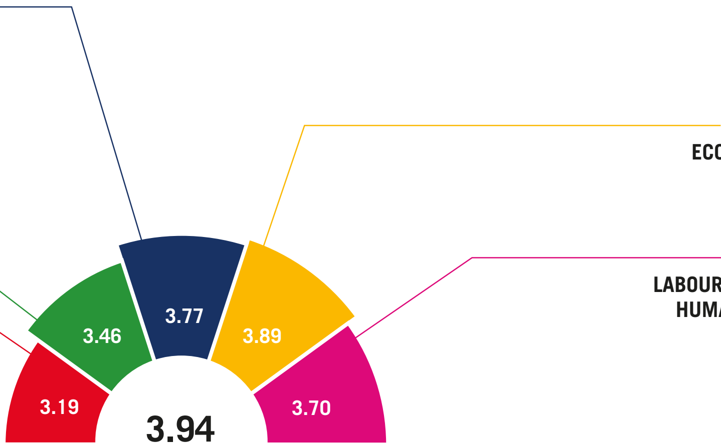
**GDP US$ (2021)**
23,315,081 MILLION



# VIET NAM

**POPULATION (2021-2022)**
**97 MILLION**

**GDP US$ (2021)**
**366,138 MILLION**



# ANNEX E

# TECHNICAL NOTES: MARITIME COUNTRY PROFILES INDICATORS

## 1. TECHNOLOGY AND INNOVATION ENVIRONMENT

### 1.1 Technology availability (15 individual technologies)

- Cloud computing
- Big Data Analytics
- Internet of Things
- E-commerce and digital trade
- Distributed ledge technology
- Augmented and Virtual Reality
- Artificial Intelligence
- Industrial robots and drones
- Fully autonomous ships
- Smart ships
- Remotely controlled ships
- Fleet monitoring centres
- Green retrofitting of ships
- Green retrofitting of port super/infrastructure
- Port automation

### 1.2 Technology business activeness

- Digitalisation enabling technologies
- Ship automation and autonomy enabling technologies
- Ship digitalisation enabling technologies
- Port automations and autonomy enabling technologies
- Port digitalisation enabling technologies
- Supply chain digitalisation enabling technologies

### 1.3 Innovation environment

## 2. LABOUR MARKET AND HUMAN CAPITAL

### 2.1 Education and training

### 2.2 Skills availability: non-seafarers

### 2.3 Skills availability: seafarers

### 2.4 Labour market policies

### 2.4 Gender equality

### 2.4 Youth

## 3. ECONOMICS AND BUSINESS

### 3.1 Competitive environment

### 3.2 Infrastructure

### 3.3 Investment

## 4. SOCIAL ACCEPTANCE

### 4.1 Employee participation

### 4.2 Societal drivers

## 5. REGULATION AND GOVERNANCE

### 5.1 Technology-driven policy

### 5.2 Regulation

### 5.3 Maritime importance

## QUESTIONNAIRE DESIGN

All questions for each sub-indicator are multiple choice questions with a 1-7 range.

## BASE QUESTION FOR THE COUNTRY PROFILE

Question number 2 of the survey ("In which country is your organisation's global headquarters located?") was used as the base question for the Country Profile structure.

The total number of countries selected is 23; the parameter for choosing them was the number of respondents, defining 10 as the minimum.

## CALCULATION OF THE WEIGHT OF INDICATORS

### Weighted mean for each question

$$f = \sum_{i=1}^{n} i * p_{g_i} = \sum_{i=1}^{n} i * \frac{g_i}{x}$$

$$p_{gi} = \frac{g_i}{x}$$

f = weighted mean for each question

n = 7

i = value (1-7)

$p_{gi}$ = percentage of weight for each choice (1-7)

$g_i$ = number of total votes for each choice (1-7)

x = total of responses for each question

### Sub-indicators

$$w_s = \frac{\sum_{j=1}^{m} f_j}{m}$$

$W_s$ = final value for each sub-indicator

m = number of questions for each sub-indicator

$f_j$ = weighted mean for each question

### Indicators

$W_I$ = final value for each indicator

$$w_I = \frac{\sum_{k=1}^{t} w_{s_k}}{t}$$

Wsk = weight for each sub-indicator for each indicator

t = number of sub-indicator for each indicator

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