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TRANSPORT 2040

AUTONOMOUS SHIPS: A NEW PARADIGM FOR NORWEGIAN SHIPPING

TECHNOLOGY AND TRANSFORMATION



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TRANSPORT 2040

**AUTONOMOUS SHIPS:
A NEW PARADIGM FOR
NORWEGIAN SHIPPING**

TECHNOLOGY AND TRANSFORMATION



ACKNOWLEDGMENTS

This report is part of the study, entitled *Transport 2040: Automation, Technology, Employment – The Future of Work*, a research project undertaken by World Maritime University (WMU) and financially supported by the International Transport Workers' Federation (ITF). The ITF financial support that was provided to carry out the research for this report is gratefully acknowledged.

A team of researchers at WMU, under the coordination of Jens-Uwe Schröder-Hinrichs and Dong-Wook Song (Co-Principal Investigators), worked on this report. The initial research was carried out by Adrienne Mannov and Peter Aske Svendsen. The revision and production was done by Tiago Fonseca. The study was carried out under the overall guidance of Cleopatra Doumbia-Henry, President, WMU.

The layout of the report and the graphics were provided by Phoenix Design Aid A/S. The report was edited by Alexandra George (through Prime Production Limited).

This study is the result of almost two years of intensive research under the umbrella of the *Transport 2040: Automation, Technology, Employment – The Future of Work* Report. Our special thanks to all interlocutors consulted for this report for their valuable time, interest and openness in sharing their views and knowledge. We are grateful that they were willing to impart their experience and views. All those consulted were under a strict confidentiality policy whereby the Chatham House Rule and non-disclosure agreements were applied.

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INTRODUCTION



INTRODUCTION

As indicated in the Acknowledgment of this report, this research work forms part of the study, entitled *Transport 2040: Automation, Technology, Employment – The Future of Work*, undertaken by the World Maritime University (WMU) and commissioned by the International Transport Workers' Federation (ITF).

The main section of this study summarizes overall trends and provides a global overview about developments in all four modes of transport. However, as highlighted in its main findings, technology and automation evolves in different ways in different contexts and environments. While in some countries, certain conditions may allow a new technology to find its way to the market, in other countries such a facilitating environment may not exist. Another factor identified is that the mechanisms behind the introduction of technology and automation in transport are complex. By highlighting general trends, as was mainly done in the *Transport 2040: Automation, Technology, Employment – The Future of Work* report, a number of interesting details are presented that may help the reader acquire a better understanding of the background and the dynamics in introducing technology and automation in transport – trends that are not necessarily discernible.

The project team also felt that dedicated Technology and Transformation Reports would provide the reader with an enhanced perspective. The concept behind the format of this report is one that has adopted a unified approach to identify the drivers behind the introduction of a certain application of technology or automation in a specific country, and to discuss this application in the context of Norway. These reports focus on six enabling factors introduced in the *Transport 2040: Automation, Technology, Employment – The Future of Work* report:

1. **Technological feasibility** – Is the technology ready for its large-scale application?
2. **Economic benefits** – Has a sound business model been drawn up?
3. **Regulation and governance** – Are the regulations ready? Are the authorities supportive?
4. **Social acceptance** – Does society accept the technology?
5. **Labour market dynamics** – Is labour expensive? Is there a labour shortage?
6. **Knowledge and skills** – Are users able to master the technology?

In summary, targeted reports, on the basis of the six factors highlighted above, can clearly enrich the discussion about the future of technology and automation in transport, and also provide a sound basis to compare the situation in different

countries with the aim of predicting future trends and challenges as a result of a more automated global transport system.

Maritime transportation is fundamental to the world economy and importantly, it is a sector facing major changes due to new technologies and automation. The concept of an “autonomous ship” has recently attracted considerable attention from industry, media and labour organizations alike. The term “autonomous ship” potentially has far-reaching implications for daily life around the planet, for global finance and for the approximately 1.6 million seafarers working in shipping today.

The aim of this Technology and Transformation Report is to describe how autonomous shipping has been developing in a specific country. Norway has been identified as an apposite location to investigate the development of the autonomous ship, new technologies and their implications on seafaring labour and skills, because Norway is at the forefront of technological development, its maritime cluster is a global leader and the country has a long history of maritime seafaring.

This report therefore provides a snapshot of how autonomous shipping, in particular the Yara Birkeland – the first autonomous cargo ship in the world – is developing within the specific context of Norway. The methodology followed ensured that comparisons between this and other studies would be undertaken in different geographical locations with different local contexts. The Technology and Transformation Reports are intended to lead to a better understanding of the technology and of particular country-specific industry factors that lead technology to develop along a particular path. With respect to the Norwegian case, conclusions are made on the future of its maritime workers based on the situational analysis undertaken in this report.

This report argues that Norwegian seafaring is at a crossroads in terms of the development of new job types and the required seafaring skills to execute them. While the autonomous ship has received considerable attention, what the report will refer to as “digitalization” more broadly is incrementally changing seafaring skills and the technical qualifications that will be required in the industry.

Within the context of the so-called Industry 4.0, the industry has bought into the idea of autonomous ships, with several stakeholders bringing the idea to the table once more.¹ The topic gained much traction in the industry culminating in the establishment of a Working Group on Maritime Autonomous Surface Ship (MASS) at the International Maritime Organization (IMO). It was aimed at conducting a regulatory scoping for MASS operations.

Currently, two trends are most in evidence:

1. "Remote Seafaring" deployed for autonomous and potentially unmanned ships; and
2. the "digitalization" of ship labour, which will likely continue.

The former will be introduced for specific maritime transportation solutions in Norway. With Norway as a frontrunner for the development of new technologies and a strong player in tailor-made maritime education,

Norwegian seafarers may be poised to assume the role of pioneers in what we refer to as "Seafaring 4.0" locally and even globally.

In order to frame the developments of autonomy and digitalization in a Norwegian seafaring context, this report starts by briefly describing the modern history of Norwegian shipping and seafaring. This will be followed by an introduction to the digital technologies informing these developments. In that regard, this report provides an illustration of the differences between the autonomous ship and examples of digitalization in shipping in the Norwegian context. This leads to a discussion of how these trends may point toward new types of maritime jobs and skills, and, in turn, to how new professional requirements are being met by educational innovation in Norway. Finally, the report discusses how Norwegian seafarers experience this particular maritime context in their country in terms of their career aspirations and trajectories and what role a seafaring career plays in their lives more broadly.

¹ IMO (IMCO) addressed automation in ships from the perspective of the different systems in vessels as early as at the 8th session of the Maritime Safety Committee on 9 March 1964 in a note by the Secretariat.

BACKGROUND: NORWEGIAN MARITIME HISTORY



A

A. BACKGROUND: NORWEGIAN MARITIME HISTORY

Historically, Norway has been one of the most maritime dependent nations in the world, and shipping has been a staple of the economy since the age of sailing.² It used to be a so-called “embedded maritime nation”, meaning that it had a large merchant fleet which flew the Norwegian flag and Norwegian nationals served as crews on these ships. They were “embedded” because income from the Norwegian shipping industry and seafaring salaries were integrated into the national economy.³

During the last 50 years, offshore oil and gas industry, fishing and the maritime trade have been the drivers of Norwegian maritime innovation. The offshore industry in particular has brought both vast wealth and investments in maritime activities. Incremental innovations in a closely connected cluster have been a part of Norway’s maritime history throughout this period. Norway is home to more than 3 per cent of the world fleet in tonnage⁴ and, as of 2015, held the sixth place as the largest seafaring nation in terms of operated tonnage⁵. The country scores 6.22 in the WMU Maritime Profile Index (see Figure 1 for more details).

Norwegian maritime history resembles the developments in shipping globally. The liberalization of Flag State regulations in the nineteen eighties enabled the outsourcing of maritime labour from embedded maritime nations, where shipowners and seafarers held the same nationality, to countries where the cost of labour was and continues to be cheaper. This led to a massive fall in the number of seafarers working in shipping from the U.S., EU and other Western maritime nations, like Norway, where the cost of labour is seen as prohibitive.⁶ There are currently approximately 1.6 million seafarers worldwide working within the merchant maritime fleet, and according to a report published by the Norwegian Maritime Authority, approximately 12,000 Norwegian seafarers were registered in 2015⁷.

As the number of Norwegian seafarers in commercial trade decreased significantly, the exploitation of oil and gas reserves in Norwegian national territory began apace, creating sizeable job opportunities for offshore seafarers. Offshore employment of Norwegian seafarers remains high, as does in-land ferry operations. Through competition and knowledge sharing across the offshore and maritime shipping industries, a comprehensive cluster of maritime expertise among engineers, technical developers, investors, regulators and worker organizations has emerged to create a world-leading maritime industry.⁸ Some refer to this cluster as a “super cluster”, meaning that Norway is a global leader in know-how in this area.

U.S., EU and other Western shipowners have operated on increasingly tight margins over the last 50 years, with crew costs often the only variable left to reduce. It is therefore understandable that the introduction of new technologies, and specifically a term like “autonomous ship”, might arouse concern for the future of seafaring jobs, as this new technology could be regarded as yet another move to curtail seafaring jobs.

However, an “autonomous ship” is not just a vessel equipped with a lot of very advanced technology that is part of what is regarded as a trend in crew reductions. On the contrary, it is an entirely new class of ship that currently does not operate like, or compete with, the commercial shipping fleet. The amount of manning needed both on ship and on shore is quite different. Further, autonomous ships will be introduced into and operate alongside existing trends in ship operations in the same way as increasing computerization. The experts consulted for this report refer to this as the increasing “digitalization” of ships, a term that will be used in this report.

² Lewis R. Fischer and Even Lange, eds., ‘Introduction: New Directions in Norwegian Maritime History’, in *New Directions in Norwegian Maritime History* (Liverpool University Press, 2011), <https://doi.org/10.2307/j.ctt21kk3cs>.

³ ILO, *The Global Seafarer: Living and Working Conditions in a Globalized Industry* (Geneva: International Labour Office, 2004), 58.

⁴ Authors’ calculation based on the UNCTAD data on merchant fleet by country of beneficial ownership in 2018.

⁵ Norges Rederiforbund - Norwegian Shipowners’ Association, ‘Konjunkturrapport [Economic Report] 2016’, 2016, <https://issuu.com/maritimframtid2/docs/konjunkturrapport-2016-no-final/1?e=16847899/34665519>.

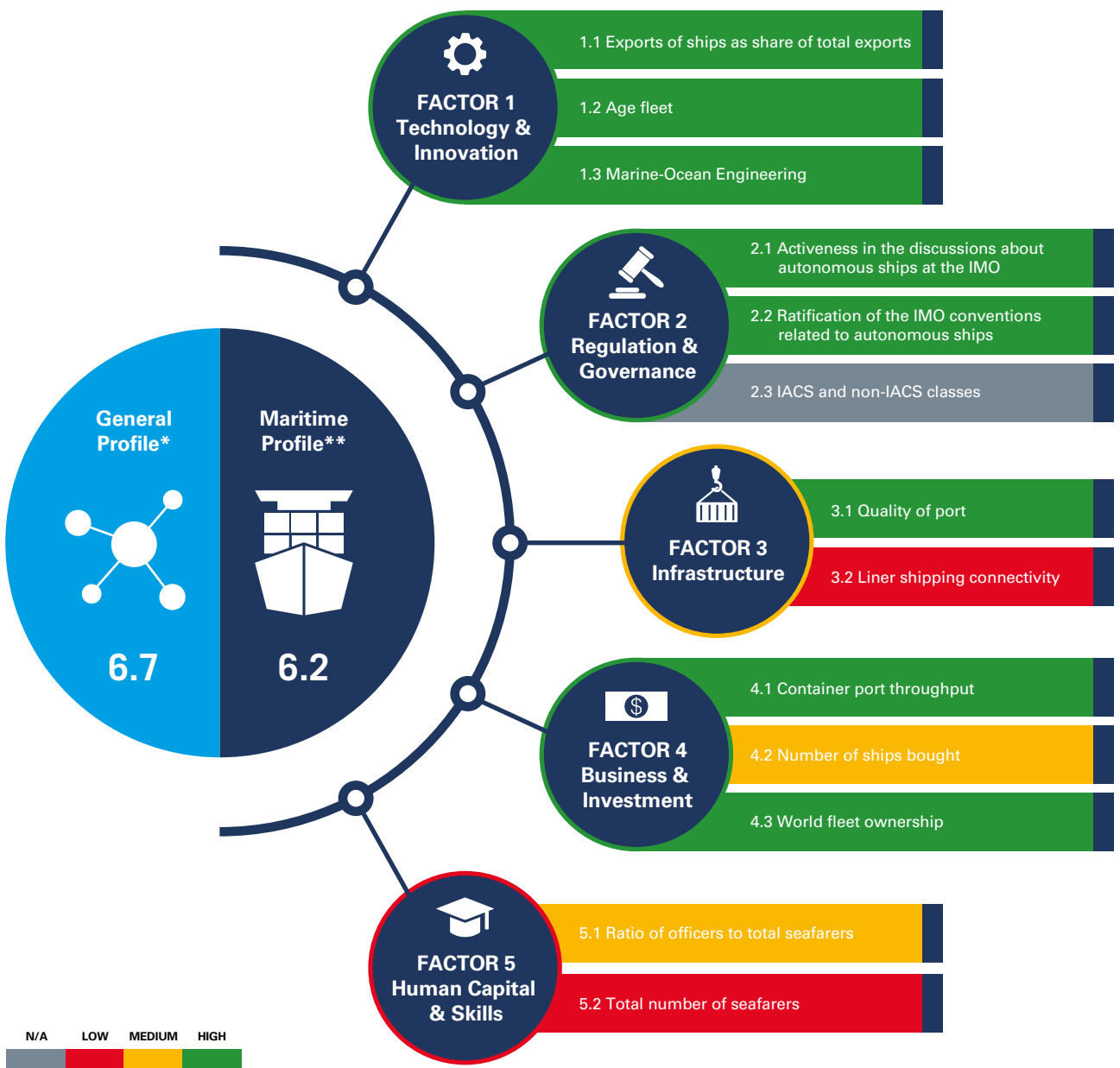
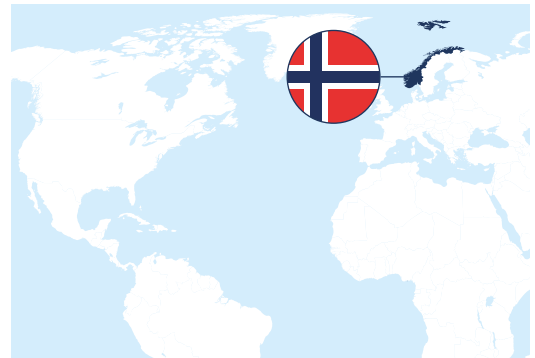
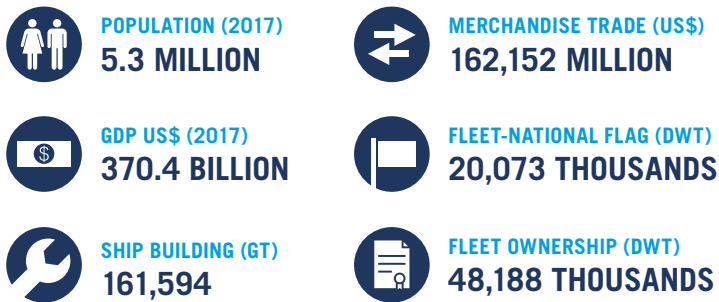
⁶ ILO, *The Global Seafarer*, 57-62.

⁷ Sjøfartsdirektoratet - Norwegian Maritime Authority, ‘Årsrapport [Annual Report] 2015’, 2015, <https://www.regjeringen.no/contentassets/ab7b70cc80924f038a26a89417d0eb66/2016/arsrapporter-2015/arsrapport-2015-sjofartsdirektoratet.pdf>.

⁸ Torger Reve, Terje Lensberg, and Kjell Grønhaug, *Et Konkurransedyktig Norge [A Competitive Norway]* (Oslo: Tano, 1992).

FIGURE 1 WMU Maritime Profile – Norway

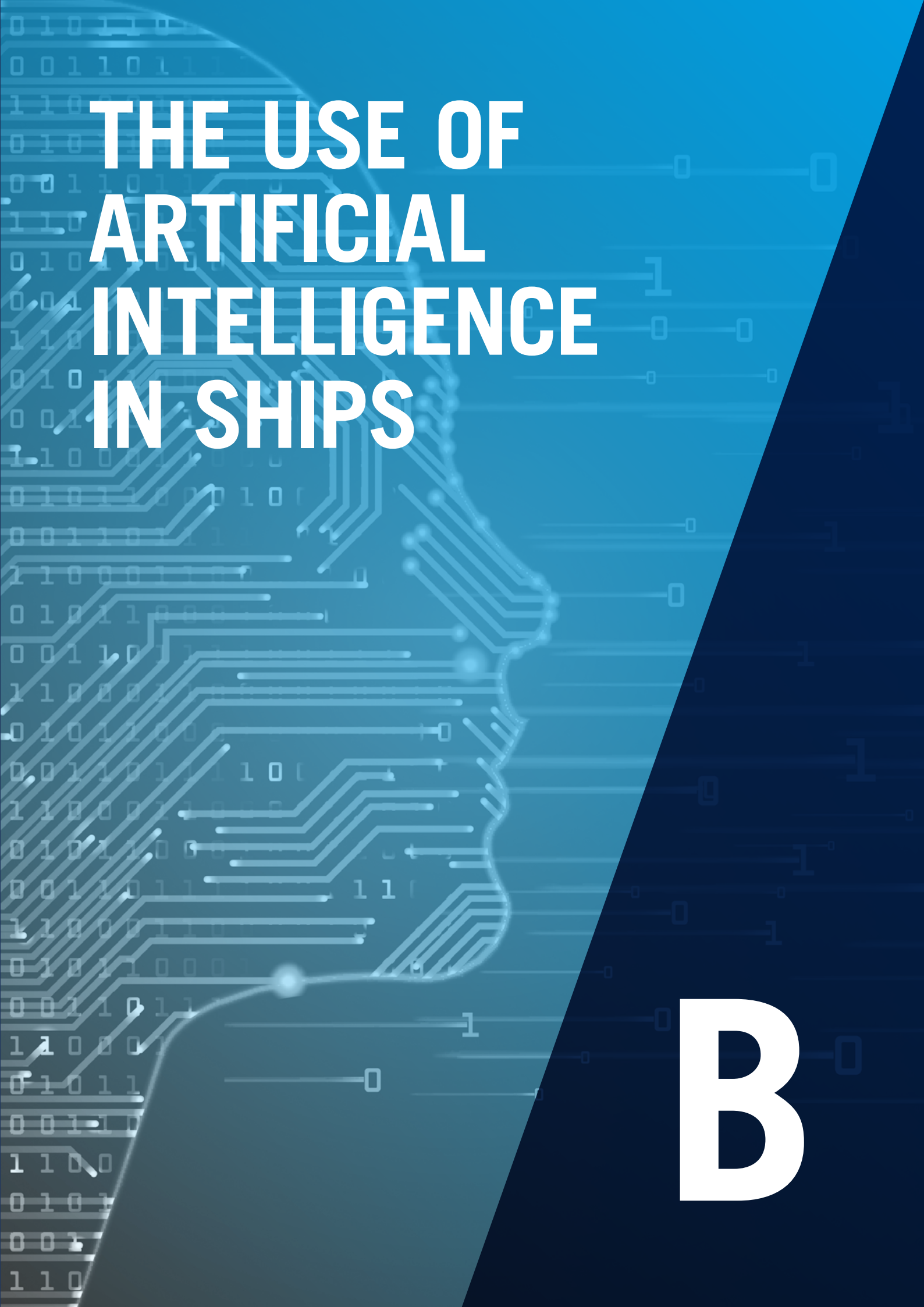
KEY MARITIME INFORMATION FOR 2017



* Composed of performance indicators related to the adoption of new technologies.

** Composed of performance factors related to the adoption of new technologies specific to the maritime field.

Source: WMU Country Profiles.



THE USE OF ARTIFICIAL INTELLIGENCE IN SHIPS

B

B. THE USE OF ARTIFICIAL INTELLIGENCE IN SHIPS

As discussed in the introduction to this report, what is significant about recent developments in technology is the reliance on growing digitalization, turning bits of offline knowledge into computable pieces of data, heightened computational ability and more sophisticated Artificial Intelligence⁹. What this means in practice is that “coders” or computer programmers can design algorithms¹⁰ for specific, data-driven and tailored purposes, namely, the central components of a programme. It is “an abstract, formalized description of a computational procedure”¹¹. Building on this, “Algorithms + Data Structures = Programmes”¹². Depending on what kind of data a programmer has and what he/she wants to do with it, it will be stored and organized differently. This is the “data structure”.

At the turn of the millennium, access to massive amounts of digital, and significantly, *online* data and unprecedented levels of computational power enabled the increased use of something called “machine learning”. This was a new approach to the work that algorithmic programmes perform. Where previously algorithms were designed to organize data into categories determined by the programmer, “machine learning” is based on algorithmic programmes that recognize patterns themselves based on statistical relationships.¹³

Being a subset of Artificial Intelligence, machine learning relies on statistical models applied to large-scale datasets to predict and decide. This process is becoming central to applications in a variety of sectors. Amazon, for example, uses machine learning to predict what products a customer might like to buy based on his/her previous buying and search behaviour¹⁴. Machine learning includes something called “neural networks” that is modelled on what we know about how the brain incorporates information. It is described as a:

// ...model composed of a network of simple processing units called neurons and connections between neurons called synapses. Each synapse has a direction and a weight [vector], and the weight defines the effect of the neuron before on the neuron after.¹⁵ //

In 2012, another machine-learning technique appeared: “deep learning”. Deep learning is one factor that explains why so much attention has been accorded to AI in recent years. Deep learning has the capacity to independently identify patterns in large amounts of complicated, unstructured data, and to generate predictions through a neural network model. This invention in the field of computer science can predict behaviour and outcomes that previously only human beings could undertake. Deep learning is central to the functioning of autonomous vehicles and, potentially, autonomous processes in shipping.

Machine-learning, deep learning, access to large amounts of structured and unstructured data and the computational power to use the data has had an enormous impact on the development of recent general technologies, such as robotics, sensors, image and sound recognition, blockchain and the “Internet of Things” (IoT). These general technologies find application in some of the products we see transforming our lives today and in semi- or fully automated and digitized work processes carried out in shipping.

⁹ The term “Artificial Intelligence” was coined in 1956 at a conference at Dartmouth College. It was originally regarded as a futuristic vision, but with the growth of computerization deemed fantastical in scope the vision has become a reality. Pamela McCorduck, *Machines Who Think: A Personal Inquiry into the History and Prospects of Artificial Intelligence* (Massachusetts: A.K. Peters Ltd).

¹⁰ An algorithm is “a sequence of instructions that are carried out to transform the input to the output.” Ethem Alpaydin, *Machine Learning: The New AI*, MIT Press Essential Knowledge Series (Cambridge, MA: MIT Press, 2016).

¹¹ Paul Dourish, ‘Algorithms and Their Others: Algorithmic Culture in Context’, *Big Data & Society* 3, no. 2 (2016): 1–11, <https://doi.org/10.1177/2053951716665128>.

¹² See Dourish.

¹³ Alpaydin, *Machine Learning*.

¹⁴ A. Mackenzie, “The production of prediction: What does machine learning want?” in *European Journal of Cultural Studies* 2015, Vol. 18(4-5), p. 431.

¹⁵ Alpaydin, *Machine Learning*.

METHODOLOGY



C

C. METHODOLOGY

The insights presented in this report are based on interviews with stakeholders involved in the Norwegian development of autonomous ships and seafaring labour, in visits to key sites in Oslo and Trondheim, Norway, as well as on a literature review. The research team conducted 18 in-depth interviews, spent time with seafarers at their workplaces and reviewed sites like the Trondheim Fjord test-bed for autonomous vessels. The research team engaged with the Norwegian maritime cluster of maritime labour and educational stakeholders, technology experts (computer science and engineering), technical developers, regulators and classification societies.¹⁶

Norway is a single case that illustrates the complexity of technological developments within the transport sector and how unevenly these developments impact local labour groups. This report should be regarded as a case study. Therefore generalized conclusions should not be extrapolated as being broadly applicable. For the developments described in this report, they will manifest themselves differently in other countries and settings.

¹⁶ For an overview of methods, including participant observation, and focus groups, as well as different kind of interviews and observation, see Kathleen Musante DeWalt and Billie R. DeWalt, *Participant Observation: A Guide for Fieldworkers*, 2nd ed (Lanham, Md: Rowman & Littlefield, Md, 2011).

AUTONOMOUS SHIPS: THE CASE OF NORWAY



D

D. AUTONOMOUS SHIPS: THE CASE OF NORWAY

D.1 AUTONOMOUS SHIPS AND DIGITIZED SHIPS

One of the major insights that have emerged from this study in Norway is that, according to one of the technical experts who was consulted, “Autonomous ships are not conventional vessels without a crew”. Although there is some overlap, the infrastructural logistics informing their use are different. In order to clarify this difference, the report will begin with a clarification of what is meant by an “autonomous ship”. Technical experts operate with a *scale* of autonomy, rather than binary categories of “autonomous” and “not autonomous”.

Several scales exist for vehicular autonomy, such as the ones from Lloyd’s Register, the Society of Automotive Engineers (SAE), the *Verband der Automobilindustrie* (Association of the Automotive Industry) and the Norwegian Forum of Autonomous Ships¹⁷. More recently, the IMO Maritime Safety Committee in the context of the maritime autonomous surface ships has come up forward with a working scale aimed at assisting the review of IMO regulations. The levels of autonomy are summarized as follows¹⁸:

- **Degree one:** Ship with automated processes and decision support. Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised, but with seafarers on board ready to take control.
- **Degree two:** Remotely controlled ship with seafarers on board. The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions.
- **Degree three:** Remotely controlled ship without seafarers on board. The ship is controlled and operated from another location. There are no seafarers on board.
- **Degree four:** Fully autonomous ship. The operating system of the ship is able to make decisions and determine actions by itself.

The report will now discuss the concept of actual “autonomy”, the last point along the scale, when decisions are made independently by the system and human beings cannot intervene. “Constrained autonomous” systems involves human supervision and limits may be integrated into the system, but a human does not make the decisions¹⁹. Apart from the category “no automation”, all of these levels include the use of some amount of data generation. This can be done manually by analysing data and making human suggestions for change/optimization or, in the most autonomous instance, systems can be programmed to use the data to train itself, with no need for any human interaction. In that regard, all examples concerning any level of autonomy include some form of digitalization.

It is, however, important to note that the opposite does not hold true: examples of digitalization are not synonymous with autonomy, or even to be understood as the harbinger of autonomy. In other words, the evidence does not point to the development of digitized applications as a linear progression toward full autonomy. It is not a question of systematically substituting existing shipboard tasks until they have all been made autonomous, thus turning it into an autonomous ship. In the words of one of our technical interlocutors, “Autonomous ships are not conventional ships without a crew”. Rather two strands can be observed, namely, a bifurcation in development: autonomous ships are like the Yara Birkeland and smart ships are the result of increased digitalization of the industry (Figure 2).

Within the Norwegian context, the first trend is exemplified by the development of the ship Yara Birkeland, which is designed to operate autonomously, with or without a crew on board. This ship is currently being built, and experts suggest it will be in operation by 2020 according to the latest official update²⁰. We are citing the example of the Yara Birkeland (Figure 3) specifically because it will be the first autonomous container ship in the world and because the business model informing it is radically different from the shipping business model to which we are accustomed. This new business model may serve as

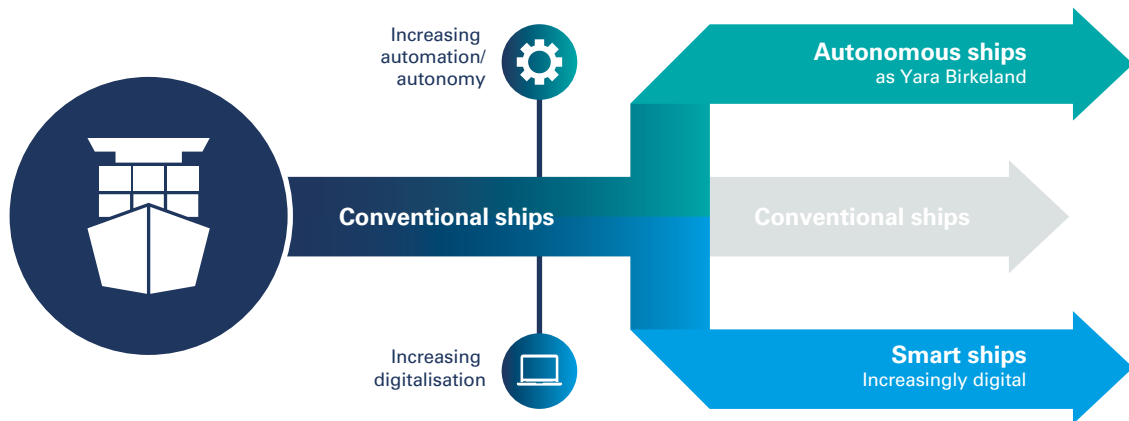
¹⁷ Lloyd’s Register is an industry classification society, the Society of Automotive Engineers (SAE) and the Verband der Automobilindustrie (VDA) are standard-developing organizations. The Norwegian Forum of Autonomous Ships (NFAS) is a Norwegian knowledge-based organization.

¹⁸ Definitions as per the IMO, ‘Regulatory Scoping Exercise for the Use of Maritime Autonomous Surface Ships (MASS): Report of the Working Group’, MSC 100/WP8 (London, 6 December 2018).

¹⁹ Ørnulf Jan Rødseth, ‘Safe Human Interaction in Autonomous Shipping’ (2017), <https://www.sintef.no/globalassets/project/hfc/documents/4-safe-autonomy-or.pdf>.

²⁰ According to a Yara official source, the expected date for the launch of the Yara Birkeland is early 2020. Yara, ‘Yara Selects Norwegian Shipbuilder VARD for Zero-Emission Vessel Yara Birkeland’, 2018, <https://www.yara.com/corporate-releases/yara-selects-norwegian-shipbuilder-ward-for-zero-emission-vessel-yara-birkeland/>.

FIGURE 2 Bifurcation in development - autonomous ships and smart ships



an inspiration for more such type of vessels to be built in the future, a trend that the report will return to shortly.²¹

The second trend is digitalization within existing merchant cargo ships, which will continue and most likely intensify. This involves the increased computerization of systems, possible fuel shifts and increased monitoring of engine and navigational systems. Within the Norwegian context, new and stricter fuel emission regulations are being introduced²². These regulations are an integral part of the push toward more digitalization in Norwegian shipping, as digitized systems can

effectively and efficiently monitor and optimize fuel emissions thereby making it easier to comply with the regulations and to save operational expenses on fuel.

In addition, electric and other alternative propulsion systems are being subsidized by the government²³, which also lend themselves to digital monitoring. Finally, although new digitalization trend within traditional shipping may not be regarded as a step toward becoming fully autonomous, these developments may certainly serve as sources of inspiration for the development of autonomous ships.

FIGURE 3 Yara Birkeland - first autonomous container ship in the world under construction



© Yara and Kongsberg Maritime

²¹ It is important to note that the Yara Birkeland project is subsidized by the Norwegian Government in the amount of approximately NOK 133.6 million (USD 15.6 mn at the March 2019 exchange rate) because of the expected reduction of NO_x and CO₂ emissions. The vessel has the potential to reduce about 40,000 journeys per year by diesel-powered trucks. Source: Yara.

²² Norwegian Maritime Authority, 2018. These regulations may be seen in relation to recent IMO emissions regulations (see page 23 of this report for the discussion of these regulations). Sjøfartsdirektoratet - Norwegian Maritime Authority, 'Emissions to Air', 2016, <https://www.sdir.no/en/shipping/vessels/environment/prevention-of-pollution-from-ships/emissions-to-air/>.

²³ Office of the Prime Minister. 3 March 2014. Regjeringen, 'Norges Strategi for Internasjonalt Samarbeid for Reform Av Subsidier Til Fossile Brensler [Norway's Strategy for International Cooperation for Reform of Subsidies to Fossil Fuels]', 2014, <https://www.regjeringen.no/no/dokumenter/strategi-fossile-brensler/id765000/>.

D.2 AUTONOMOUS SHIPS ARE VERY DIFFERENT FROM CONVENTIONAL SHIPS

The following paragraphs describe the autonomous ship within its specific Norwegian iteration and business model and the technological applications that will define its operation. This report addresses traditional shipping within its specific Norwegian context, the conventional business model within which it is embedded and the technological applications being introduced into its operations. This will lead to a discussion on the job tasks and skills needed given these developments, and, finally, on the implications this may have for educational demands and their impact on the working lives of Norwegian seafarers in 2040.

The Yara Birkeland will be a fully electric autonomous container ship carrying fertilizer products from Yara’s production site in Herøya to the nearby ports in Brevik and Larvik in Norway’s southern Telemark region (see Figure 4). The development of the ship and its technical systems is coordinated by the Norwegian engineering company KONGSBERG, and involves a myriad of different Norwegian technology developers with specific expertise that forms part of the “maritime cluster” described before.

The Herøya-Brevik-Larvik maritime transport route does not yet exist. Presently, 40,000 truckloads of Yara products are driven along the winding two-lane route, comprising the mostly mountainous roads of Norway, to the ports²⁴. This means significant wear and tear on the roads and makes local traffic difficult. As such, the maritime transport route the Yara Birkeland is to serve is not the one that traditional

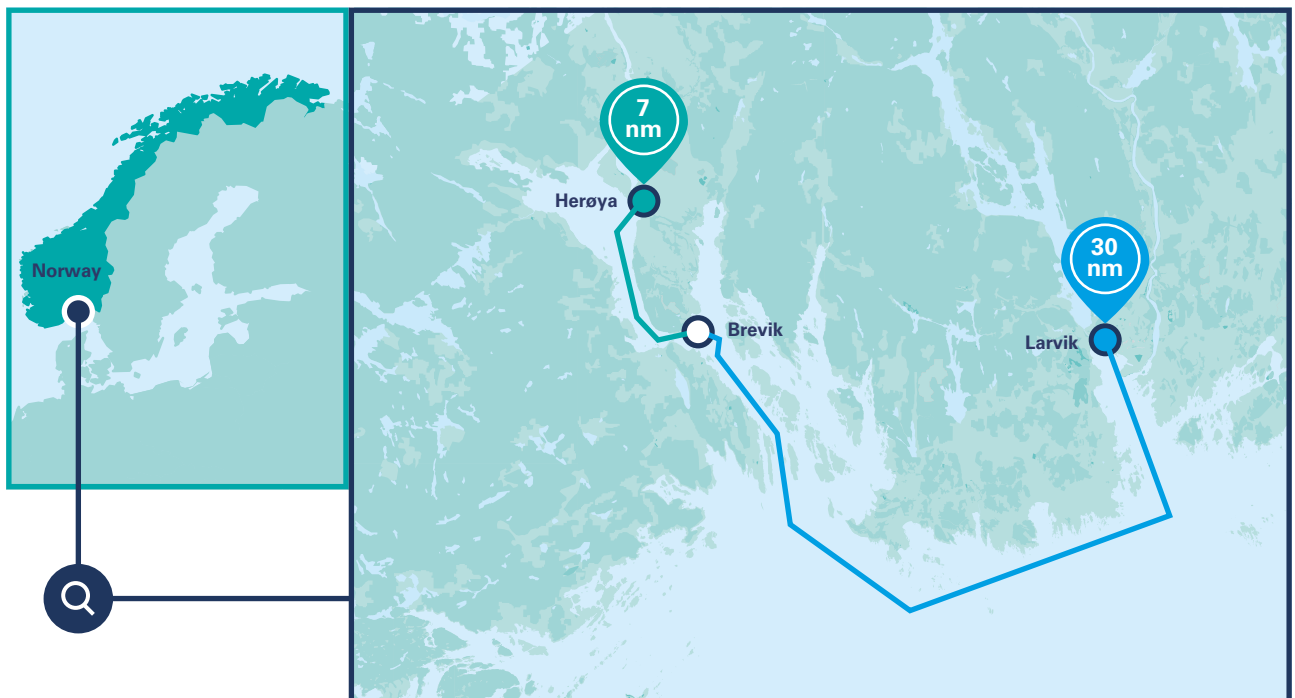
vessels currently use. This new maritime route has been created specifically with the goal of changing how Yara’s product is transported²⁵.

Yara’s operational framework for navigation, propulsion, maintenance, and data usage is fundamentally different from that of a traditional ship. In the words of one technical interlocutor, “Yara is not really a ship” because its business model is fundamentally different. The Yara Birkeland is not owned by a shipowner whose *raison d’être* is to move cargo. As one of our technical experts explained:

“...the expectation from the Yara is that it will be an economically viable alternative to truck transport (...) and much more environmentally friendly. This is basically what we expect will happen in other cases. Replacing a conventional ship on international waters with an autonomous ship doesn’t make sense. You have to look at the total transport system (...)”

The idea of operating within a total transport system challenges the business model in which the service provided is the movement of cargo from A to B. Instead, the “total transport system” as a business model is focused on the smaller scale and involves a new kind of flexibility:

FIGURE 4 Routes served by the Yara Birkeland



²⁴ Yara, ‘The First Ever Zero Emission, Autonomous Ship’, 2018, <https://www.yara.com/knowledge-grows/game-changer-for-the-environment/>.

²⁵ In that regard, the introduction of the Yara Birkeland will adversely affect truck drivers.

// However, if you start to think about it: we no longer want to have a 20,000 TEU anymore, we want to have a 3,000 to 4,000 TEU, associated with a more flexible system involving calls on smaller ports, more ports, a more direct route. In that regard, autonomous ships are probably an enabling factor for developing this type of transport system. So the main point is that an autonomous ship is not a conventional ship without a crew – it is a totally new phenomenon. (...) In fact, all the viable proposals are actually new transport systems (...) All the business models we are investigating are not comparable to conventional shipping. //

The Yara Birkeland is owned by a manufacturer of fertilizer, the company “Yara”, and the sole function of the ship is to transport the manufacturer’s product along a very specific route, to a port where it can be further shipped globally. The Yara is not designed to move other products nor meant to operate outside Norwegian territorial waters. Rather it was designed to operate only along specifically

designated routes that offer easier transportation of the product than roads can offer.

Norway has a specific goal of getting trucks off the Norwegian roads and to reduce emissions generally²⁶. Yara’s autonomous ship is designed to address the company’s specific need for low emissions and the efficient transportation of its product, tailored to the specificity of Norway’s fjord landscape. In addition, the Yara Birkeland was developed in an environment where the expertise required to address this specific engineering challenge is available.

Our interviews also indicated that Norway has a “short distance” between producers and users and a so-called “flat”, or democratic, social hierarchy, meaning that lessons learned by users are easily communicated to producers. This ability to share criticism and practical advice has fed technological innovation in Norway²⁷.

Finally, in a country where seafaring expertise, history and identity is strong, but in which seafaring labour has been on the decline since the nineteen eighties, in part due to comparatively high labour costs²⁸, the argument for making an autonomous and unmanned ship is strong. In other words, a unique combination of factors has enabled the emergence of autonomous ships.

D.3 YARA BIRKELAND AND AUTONOMOUS SHIPS

The Yara Birkeland may be regarded as disrupting the ways that supply chain transportation is practiced in Norway. According to the technical experts that were consulted for this study, within three to five years the Yara Birkeland’s first operational phase as a remotely controlled and manned vessel will take place. In coming years, we will see a shift to remotely controlled-unmanned ships, then to autonomous-unmanned vessels. The last two phases indicate a shift from decision support to decision taking, although shore-based supervision will remain a central activity.

The following paragraphs describe the different functions integrated into the Yara Birkeland. They are divided into navigational functions, propulsion systems and the integration of data. Some of the critical and challenging technical aspects of deploying fully autonomous ships, such as the Yara Birkeland, are also presented. Thereafter,

our description of the Yara Birkeland points toward other similar business models where autonomous ships could be developed in Norway and even in other locations, given the right circumstances.

Navigation

What makes navigation possible with remote control from the shore are a wide range of sensors, including radar, lidar²⁹, AIS³⁰, cameras and IR cameras³¹ and existing navigational innovations, such as route-planning, an Electronic Chart Display and Information System (ECDIS) and dynamic positioning programmes. From three shore-based control centres the data provided by these sensors will be monitored and potentially controlled via maritime broadband radio, satellite communications and GSM³². Mooring and berthing

²⁶ Office of the Prime Minister, 1 December 2014. Regjeringen, ‘Miljøvennlig Transport [Environmentally Friendly Transport]’, 2014, <https://www.regjeringen.no/no/tema/klima-og-miljo/forensning/innsiktsartikler-forensning/miljoennlig-transport/id2076774/>.

²⁷ Tone Merethe Aasen et al., ‘In Search of Best Practices for Employee-Driven Innovation: Experiences from Norwegian Work Life’, in *Employee-Driven Innovation a New Approach*, ed. Kirsten Moller et al. (Basingstoke: Palgrave Macmillan, 2012); Gabriel R.G. Benito et al., ‘A Cluster Analysis of the Maritime Sector in Norway’, *International Journal of Transport Management* 1, no. 4 (2003): 203–15, <https://doi.org/10.1016/j.ijtm.2003.12.001>.

²⁸ ILO, *The Global Seafarer*, 58-60.

²⁹ “LIDAR, which stands for “Light Detection and Ranging,” is a remote sensing method that uses light in the form of a pulsed laser to measure ranges, or variable distances, to the Earth.” NOAA, ‘What Is LIDAR?’, 2018, <https://oceanservice.noaa.gov/facts/lidar.html>.

³⁰ “AIS” stands for “Automatic Identification System”, which transmits the position of a ship via satellite. Each ship making such transmissions has a unique AIS number which enables users to retrieve information about the vessel, such as last port of call, the ship’s IMO number or its next port of call. According to the IMO, all vessels trading in international waters over 300 gross tonnage must use AIS technology. Thus, AIS is not unique to autonomous ships. IMO, ‘AIS Transponders’, 2018, <http://www.imo.org/en/OurWork/safety/navigation/pages/ais.aspx>.

³¹ “IR” stands for “infrared”. An infrared camera measures temperature, which is then converted into an electronic signal and further processed so that it appears as an image.

³² “GSM” stands for “Global System for Mobile Communication”. GSM digitizes and compresses data that is transmitted via mobile communications systems.

will also be handled autonomously and will not require human handling.

In terms of AI technology, the sensors listed above either turn data into images, such as with the IR camera, or turn images into data, such as with image sensors. These images and data are fed into the navigational programme, including information from route-planning systems, static data available through ECDIS and data provided from dynamic positioning systems. All of this data also serves to “train” the autonomous programme so that it becomes better at interpreting the various data sources in order to optimize autonomous decision-making.

The integration of these data sources will be examined in a section below. Based on the information provided, the Yara Birkeland will begin with a removable bridge and will be manned so that operators can intervene on site if necessary. In time, the bridge is expected to be removed and the ship will be entirely operated from shore-based control centres. The experts interviewed do not expect the vessel’s operation to ever reach a stage where no supervision is required, but they do expect it to operate autonomously, with shore-based supervision and human intervention only required in exceptional situations. From a labour perspective, such changes will have far-reaching implications for the future educational needs of seafarers.

Propulsion

The Yara Birkeland runs on electric power that is provided by batteries rendering the vessel one hundred per cent emissions-free at source. Because the cargo load is specialized for a specific route, the need for ballast weight will be constant. The battery pack provides this weight. Data will also be generated from how the ship’s propellers and thrusters interact with the marine environment, such as wind, wave size and current, which is part of the dynamic positioning system.

D.4 CRITICAL CHALLENGES AND COSTS

Experts described potential challenges for developing and employing autonomous and unmanned ships and these relate to safety, classification and the regulatory framework. These challenges are automating “situational awareness”, the digitalization of ColRegs³³, mixed traffic and the predictability of deep-learning functions.

The Yara Birkeland as a maritime vessel in operation does not yet exist. A model of the vessel was tested late in 2017 and the VARD Braila shipyard in Romania has been tasked with building the hull of the ship at a total cost of NOK 250 million (about USD 29 mn at the March 2019 exchange rate).³⁴ Thereafter Kongsberg will coordinate

As with the navigational systems described above, this data will be used to monitor the ship’s passage and performance, but just as importantly, it will also serve to train the integrated and autonomous system to perform even more optimally and, in time, autonomously. From a labour perspective, such systems require a stronger focus on electrical and computer engineering and less focus on mechanical marine engineering. This has significant implications for the educational needs of marine engineers moving forward.

Integration of data

Digitalization in navigation and propulsion systems generates an enormous amount of data. For an autonomous system to work, this variegated data needs to come together for monitoring and control in a shore-based control centre. One of the major uses of this data is system optimization, especially given the regulatory and financial incentives to save on fossil fuel. In that regard, big data offers the opportunity to “tweak” operations to use resources as efficiently as possible.

But this form of optimization can also refer to other resources and becomes particularly relevant when considering the optimization of logistics. Significant amounts of time can be lost at intermodal transportation hubs, for example when transferring goods from the factory to the ship. Kongsberg, the technical developer behind the Yara Birkeland, already has information management systems that integrate information from a variety of locations and devices. They do not use the term Internet of Things (IoT) in their promotional information, but integrating data from a variety of devices across different locations is precisely what an IoT does.

Increasing reliance on information management systems and optimization through “big data” will create a demand for data analytics experts and system controllers to be employed at shore-control centres. Manning such centres will require workers with a maritime and digital education.

the fitting of the rest of the ship with the navigational and the propulsion system (the latter has already been commissioned with Brunvoll) and the information systems described above. For these reasons, it is not clear what additional technical hurdles the vessel may encounter once in operation. The total cost of the project is estimated to be around NOK 400 million (about USD46 mn at the March 2019 exchange rate)³⁵, with one third of this cost financed by State subsidies because of the emission reduction from trucks.

³³ “COLREGS” is an abbreviation for the IMO Convention on the International Regulations for Preventing Collisions at Sea, 1972. As a ratified IMO convention it is part of international maritime law.

³⁴ Yara, ‘Yara Selects Norwegian Shipbuilder VARD for Zero-Emission Vessel Yara Birkeland’.

³⁵ World Maritime News, ‘Gard to Insure Autonomous Vessels’, 2018, <https://worldmaritimeneews.com/archives/241112/gard-to-insure-autonomous-vessels/>.

Situational awareness

Traditional merchant cargo ships already use some of the digitized applications the report has discussed above, such as sensors. Sensor input augments the crew's "situational awareness". This is a combination of the seafarer's experience, ability and perhaps even personality. However, how seafarers perceive situations and which details are integrated into an analysis of a given situation are highly subjective. Sensors can gather data, but it is not yet clear if the algorithms that guide decision-making programmes are able to integrate such subjective knowledge. According to the technical experts consulted, situational awareness, as it stands at the moment, is very difficult to code and offers challenges to the safe and efficient operations of unmanned, autonomous ships.

The digitalization of COLREGs

Since COLREGs³⁶ constitute a part of international maritime law, adherence to them is necessary for the regulatory framework governing autonomous ships, and for insurance and classification purposes. These regulations are described in qualitative terms. For example, Rule 6, "Safe Speed" specifies:

Every vessel shall at all times proceed at a safe speed so that it can take proper and effective action to avoid collision and be stopped within a distance appropriate to the prevailing circumstances and conditions.³⁷

In order for the COLREGs to be integrated into an autonomous ship, they need to be translated into programming code. What counts as a "safe speed", an "appropriate" distance and an evaluation of "prevailing circumstances and conditions" is highly qualitative and subjective. Finite values may of course be assigned by gathering knowledge from experienced

seafarers, insurers and protection and indemnity (P&I) clubs, and integrated into autonomous programmes, but the *sense of seamanship* that so many seafaring interlocutors spoke of may remain elusive. Because autonomous ships are still at an experimental phase, some of these hindrances may be addressed through exemptions during early test and operation periods.

Mixed traffic

The Yara Birkeland and similar ships will not exist in a vacuum. Other container ships plying the oceans are all currently manned. One of the challenges this poses is that even if ColRegs and situational awareness could be represented in finite values and coded, seafarers will still be on board operating other ships; they will still be following their own subjective perceptions of situational awareness and of keeping an "appropriate" distance. The issue of "mixed traffic" is a challenge that developers of autonomous vehicles also face in other transportation modes³⁸.

Complex artificial intelligence: deep-learning functions

Finally, developers of autonomous ships like the Yara Birkeland may seek to optimize its functions by integrating advanced AI functions, such as deep learning into the autonomous programmes. Deep-learning based programmes are flexible, and react to and learn from the new patterns they are programmed to identify. This may mean that situational awareness and the subjective enactment of COLREGs could be learned by a programme, but it offers significant challenges to the bodies that seek to regulate, classify and insure them. As one of our technical experts asked, "How do you insure something that is always changing?" The question of deep learning may be the next step in the programming of autonomous ships in the post-2040 period.

D.5 FLEXIBILITY: THE BUSINESS MODEL FOR AUTONOMOUS SHIPS

The case for autonomous maritime transport is first of all a business model. To date, the convincing business models involve companies with complete control over the logistical chain of their product. Autonomous shipping could be interesting for such actors as it would allow a gain in flexibility between the production and transportation of their product, in addition to generating a data-driven picture of their transportation system from production plant to final export.

Although the exploration of autonomous ships has just begun, such business models have found very limited applications and are relying solely on short, local routes in countries that host manufacturing companies with the resources to

develop innovative transportation system solutions. Future developments modelling the Yara's integrated transportation system might emerge in the coming years, according to the experts consulted.

One case involves a logging company operating on a peninsula in the Trondheim Fjord in western Norway, which has been officially designated as a test area for autonomous surface ships by collectively involving the Norwegian Maritime Authority and the Norwegian Coast Guard³⁹. The logging company currently sends diesel trucks in a circle around the fjord to arrive at a port where the lumber can be further shipped out on international cargo ships.

³⁶ IMO, 'International Regulations for Preventing Collisions at Sea (COLREGs)', 1972.

³⁷ IMO.

³⁸ See for example the ITF/OECD, 'Managing the Transition to Driverless Road Freight Transport' (Paris: OECD, 2017), <https://www.itf-oecd.org/sites/default/files/docs/managing-transition-driverless-road-freight-transport.pdf>.

³⁹ Other players involved are the Port of Trondheim and various industries, universities and independent research organizations. See Sjøfartsdirektoratet - Norwegian Maritime Authority, 'World's First Test Area for Autonomous Ships Opened', 2016, <https://www.sdir.no/en/news/news-from-the-nma/worlds-first-test-area-for-autonomous-ships-opened/>.

An autonomous ship carrying lumber across the fjord would reduce transport time and emissions. The vessel could be extremely flexible and suited to the itineraries of the ocean-going ship it is scheduled to meet at port. This change would optimize the logging company's entire transport route. Similar business models are being developed around the test region, with cargo such as gravel and fish.

Interestingly, thinking in terms of such alternative business models challenges the conventional wisdom of a business model based on economies of scale.⁴⁰ The advantage of size held by the largest shipping operators thus diminishes as the optimal transport solution is not about sheer quantity of goods, but about flexibility. This invites actors in production and manufacturing to solve their maritime transport needs themselves in order to gain logistic manoeuvrability. Smaller quantities transported with greater flexibility will replace the notion of economies of scale.

A model for autonomous passenger transport?

According to one of the technical experts consulted, short-range inland passenger ferries could be an attractive sphere for autonomous maritime operations in Norway. Due to the geography of its coastline and the political support of rural areas, Norway has quite a few smaller ferries connecting both urban and remote islands and fjord communities along its western border. As some of these ferries operate with a small number of passengers and significant seasonal fluctuations, the flexibility introduced by autonomous ferries could make for a sensible business model.⁴¹

Even though this trend is more likely tied to the goal of decreasing emissions than to build up autonomous transport, it does serve as one indication in the introduction of autonomous vessels. At this time, the possibilities of autonomous operations on such routes are increasing. As battery reach increases, the ferry routes in play for potential automation also increases thereby creating new possible business models for cruise ships and long-range ferries.

While battery-powered passenger ferries equipped with auto-crossing technology have been commissioned, no mention has been made of reducing the crew working on

board these ferries, or even making them unmanned. But these new ferries, expected to begin operation in 2019, will be equipped with many of the technical prerequisites leading to redundancies.

For this reason, short passenger ferries may be an exception to the bifurcation of technology developments mentioned earlier. In other words, for short-route passenger ferries in Norway, the gradual implementation of advanced technologies could indicate a move toward autonomous and unmanned conventional passenger ferries (except for a designated safety crew member).

In addition, the city of Trondheim is replacing its plans to build another bridge across a canal in the centre of the city with an autonomous "on demand" ferry powered by electricity⁴². This solution, named Milli-Ampere, would not hinder ship transport through the canal and would cost only 10 per cent of the cost of a bridge. For passengers, the ferry would operate like a horizontal elevator. Passengers will simply press a button to call the ferry, which will carry them across the canal. If the municipality agrees and safety modelling and testing is successful, this could be in operation by 2019⁴³.

This urban ultra-small-range ferry might serve as both a test of technical feasibility of autonomous ferries and as a device to generate social acceptance among the public incrementally. This may be of particular value for societal acceptance more broadly if there are plans to move the above-mentioned newly commissioned ferries from semi-autonomous to constrained autonomy status, with potential shore-based, remote control.

The introduction of flexibility instead of quantity as the competitive advantage, the shift from shipowners selling a transportation service to production and manufacturing companies managing their own transportation with tailor-made autonomous vessels and supply chains and the potential of autonomous passenger transport – all these factors will lead to a reordering of the traditional hierarchies of ship classifications within the Norwegian maritime cluster and potentially within shipping more broadly. This opens up a series of fundamental questions for the industry, such as, will classification societies still classify ships? Who is a shipowner? May we continue to refer to seafarers if they operate ships from ashore?

⁴⁰ ILO, *The Global Seafarer*, 18-19.

⁴¹ Recently, autonomous ferries have been successfully demonstrated. Rolls-Royce and Finferries demonstrated the first autonomous ferry, Falco, on 3 December 2018 and it navigated autonomously between Parainen and Nauvo next to Turku in Finland, where the control centre is located (see Rolls-Royce, 'Rolls-Royce and Finferries Demonstrate World's First Fully Autonomous Ferry', 2018, <https://www.rolls-royce.com/media/press-releases/2018/03-12-2018-rr-and-finferries-demonstrate-worlds-first-fully-autonomous-ferry.aspx>.) Preceding this, Wärtsilä had already demonstrated auto docking of the Norled-owned ferry, Folgefonn, in Norway in April 2018 (see Wärtsilä, 'World's First Autodocking Installation Successfully Tested by Wärtsilä', 12 May 2018, <https://www.wartsila.com/media/news/26-04-2018-world-s-first-autodocking-installation-successfully-tested-by-wartsila-2169290>.) A significant point to note is that battery-powered passenger ferries equipped with auto-crossing technology have been commissioned for the cross-fjord, Rørvik-Flakk connection near Trondheim (Rolls-Royce, 'Rolls-Royce Signs Another Deal to Supply Innovative Automatic Crossing System', 2017, <https://www.rolls-royce.com/media/press-releases/2017/10-04-2017-rr-signs-another-deal-to-supply-innovative-automatic-crossing-system.aspx>.)

⁴² Gemini Research News, 'Driverless Ferries to Replace Footbridges', 2018, <https://geminiresearchnews.com/2018/06/driverless-ferries-to-replace-footbridges/>.

⁴³ NRK, 'Foreslår Førerløs Passasjerferge i Trondheim [Proposes Driverless Passenger Ferry in Trondheim]', 2016, <https://www.nrk.no/trondelag/foreslar-forerlos-passasjerferge-i-trondheim-1.12990523>.



DIGITALIZATION IN CONVENTIONAL SHIPS: A NORWEGIAN PERSPECTIVE

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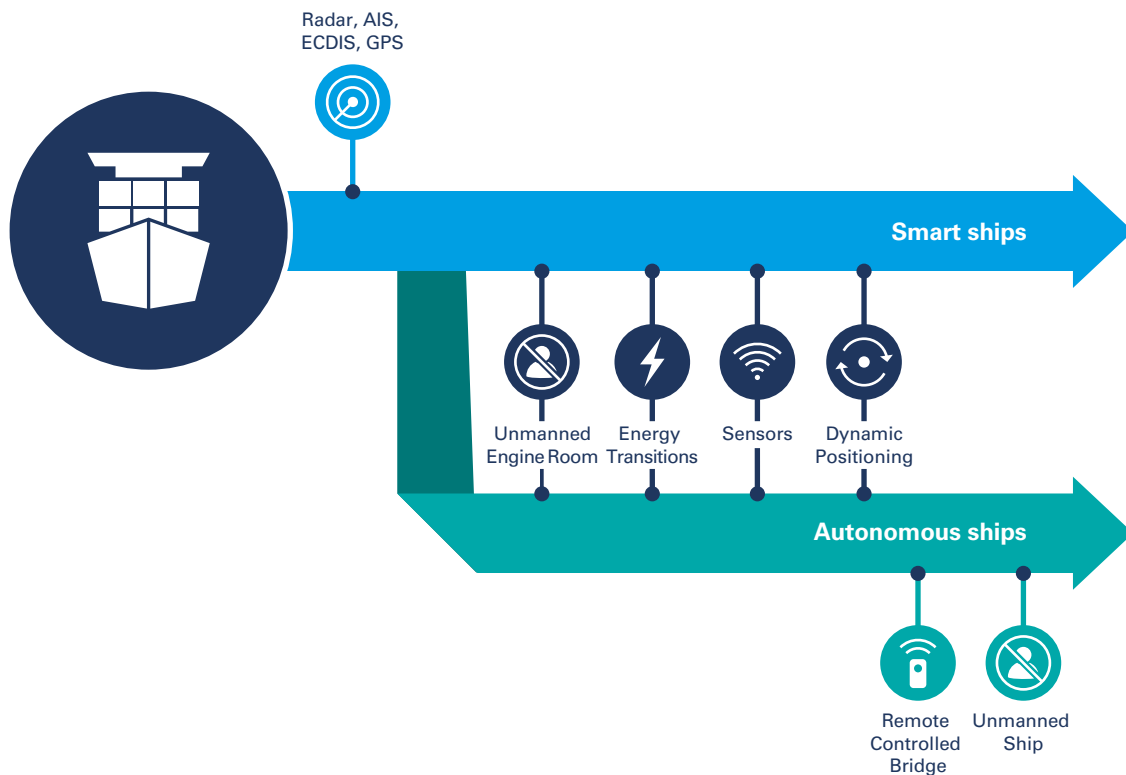
E. DIGITALIZATION IN CONVENTIONAL SHIPS: A NORWEGIAN PERSPECTIVE

The development and business cases behind the “autonomous ship” in Norway is an endeavour that is close to conventional shipping, not a further evolutionary step in the industry’s development. Nevertheless, some of the AI-based technologies that will be integrated in the autonomous ship are also slowly finding their way on board conventional ships in a process called “digitalization”. Digitalization does not necessarily lead to autonomous vessels and unmanned ships. It is a necessary but insufficient condition. Ships can

be digital without being autonomous or unmanned – see Figure 5 for a possible roadmap.

In the next paragraphs, this study will describe some of the main recent additions to conventional cargo ships presented by labour interlocutors who were consulted in Norway. The study describes these specific developments because, although no clear evidence points toward labour cuts, a link exists between these digitized applications and the kind of

FIGURE 5 Technology roadmap for autonomous ships



job's tasks and skills required. Today seafarers are already experiencing the effects of this change.

Finally, these changes must be seen within the specific Norwegian context in which they were observed. The

seafarers and labour representatives with whom our researchers met perceive their working lives, career opportunities and educational options from a specific Norwegian perspective, a theme this study will address in further detail in the section "Seafaring 4.0."

E.1 AN ONGOING TREND

Technical innovation in shipping is not new. In the modern era, we have seen the introduction of the steam engine, radio and telegraph communication, and the introduction of the combustion engine. More recently, we have seen the introduction of satellite communication, Internet on board and applications, such as electronic chart display and information system ECDIS and an automatic identification system (AIS), that build on these technologies. With heightened computational power and Internet technology in the 1980s, the generation and application of data has become a new potential source of optimization and income for shipowners.

In the following paragraphs, the study describes recent digitized applications on the bridge and in the engine and how they affect the character and tasks connected to work on board, specifically with regard to administrative, bureaucratic and leadership tasks.

Bridge

Dynamic positioning (DP) is another innovation that adjusts the ship's position according to wind, current and wave size. DP is an integral part of Yara Birkeland's operation and it is already deployed in a series of different kinds of manned vessels, such as ferries, cruise ships and offshore vessels. Through specially designed algorithms, DP maintains the ship's position in the most fuel-efficient manner.

Auto crossing was another application that was addressed by the seafaring interlocutors consulted. Auto crossing controls the use of fuel in relation to the state of the sea and the level of acceleration, deceleration, speed and track. The navigator can intervene manually if needed. Rolls-Royce has accepted a commission to supply 18 new more environmentally friendly ferries, equipped with auto-crossing technology for a Norwegian ferry operator.⁴⁴ Rolls-Royce has already carried out a test voyage with automated navigation⁴⁵. Rolls-Royce Commercial Marine has been acquired by Kongsberg Maritime, which will undertake these projects under the overall Kongsberg umbrella.

Similarly, through sensor applications, autodocking will offer heightened visibility for docking operations, which represents a new piece of autonomous technology⁴⁶.

Auto-docking and dynamic positioning will have a marked effect on the tasks of a captain.

Engine

The major incentives for engine innovation technologies are fuel-cost savings and emissions control. The applications that could be observed emerged from one or both of these incentives. These include alternative fuel and propulsion as well as data analysis. In terms of fuel, most conventional cargo ships operate on heavy fuel. Heavy fuel or bunker fuel is a low quality fuel, highly viscous and cheap. International shipping represents approximately 3 per cent of the total global anthropogenic CO₂ emissions, which is a significant number given the consequences. The IMO estimated that the "... multi-year (2007–2012) average annual totals are 20.9 million and 11.3 million tonnes for NO_x (as NO₂) and SO_x (as SO₂) from all shipping, respectively (...)." It was further indicated that "...NO_x and SO_x play indirect roles in tropospheric ozone formation and indirect aerosol warming at regional scales"⁴⁷.

For these reasons, the IMO recently introduced a new limit on sulphur content in ship fuel, from 3.5% m/m to 0.5% m/m by 2020 for all Flag States⁴⁸. This means that shipowners are rushing to find ways to reduce their emissions, either by introducing techniques like scrubbers to reduce emissions after the heavy fuel has gone through the system, or by changing fuel and/or propulsion methods altogether.

Here, the introduction of LNG, diesel-electric combinations or battery-propulsion have played central roles and were key themes in the consultations with developers and marine engineers. At the same time, the cost of heavy fuel takes up a tremendous part of the total operational expenses, in some instances, as much as 40-50 per cent of total costs. For these reasons, shipowners are eager to find cheaper alternatives that also comply with the new IMO requirements.

LNG could be a viable solution, as it consists almost completely of methane gas, and generates close to half the CO₂ that heavy fuel generates, for example. This is of particular interest because the technical experts consulted for this report suggested that LNG-run vessels would "be easier to automate" because they require less maintenance than engines running on heavy fuel.

⁴⁴ Marinelog, 'Fjord1 Orders Rolls-Royce Autocrossing System for More Ferries', 2018, <https://www.marinelog.com/coastal/ferries/fjord1-orders-rolls-royce-autocrossing-system-for-more-ferries/>.

⁴⁵ Rolls-Royce, 'Rolls-Royce and Finferries Demonstrate World's First Fully Autonomous Ferry'.

⁴⁶ See, for example, Rolls Royce's presentation of various autonomous applications for the autonomous ship, which includes auto-docking: Jann Peter Strand, 'Veien Mot Fjernstyrte Og Autonome Skip [The Road to Remote and Autonomous Ships]' (2016), http://nfas.autonomous-ship.org/nfas-161004/07_RR_pres.pdf.

⁴⁷ See page 2 of the Executive Summary of the IMO, 'Third IMO Greenhouse Gas Study 2014' (London: International Maritime Organization, 2015).

⁴⁸ IMO, 'Sulphur 2020 – Cutting Sulphur Oxide Emissions', 2018, <http://www.imo.org/en/MediaCentre/HotTopics/Pages/Sulphur2020.aspx>.

Data analysis

As with autonomous ships and shore-based control centres discussed earlier, digitalized applications on the bridge and in the engine on board conventional ships also utilize data to monitor systems and to heighten their efficiency. In fact, one chief engineer explained that his crew had a friendly and open competition with crews from the fleet's sister ships on which the crew could operate their ship most efficiently. Data registered on the engine's operation was compared manually and also served as a learning device for the team of marine engineers working with this pioneer LNG ferry. The digital data was also shared with the shipping company's shore personnel, and there was an open dialogue about how the engine could be managed safely and efficiently. This active use of operations data required that the seafarers have specific skills, which is examined in more detail under "Seafarers 4.0".

Administrative and bureaucratic tasks

Digitalization of conventional ships and the emergence of autonomous ships affect seafarers in similar ways. Both move the seafarer's attention from operation-related tasks to communication, monitoring and documentation-related tasks. In practice, this includes communication with the shipowner and authorities via e-mail. Monitoring digital systems to be sure they were working the way they were intended and using the data they generated to make operational changes for heightened efficiency also play an increasing role. One such example is the engineers that use engine data to optimize ship operations.

Documentation also appeared to play a central role, particularly as this related to compliance with IMO regulations, Port State regulations, Flag State regulations and company policy. These could include "e-certificates" for seafaring certificates, last port of call, which is part of the ISPS code, and online oil record books⁴⁹. As procedures become more digitalized, documentation of their proper execution also becomes digital. This moves the officer's tasks further away from the bridge or the engine room and, more often, to a computer screen.

One technology worth particular mentioning here is the development of the "e-bill of lading" through blockchain technology. A "bill of lading" is a legal document between the shipper and carrier detailing the type, quantity and

destination of the goods being transported. Several large shipping companies are currently pairing up with research institutions to develop a blockchain-run version of the bill of lading, which would simplify and secure the ordering process⁵⁰. Although this may not have an immediate disruptive effect on seafarers' tasks aboard a ship, it may have a significant effect on office workers in the shipping industry. One stakeholder explained:

// ...if you look at the liner shipping companies, they have a lot of people employed, and a massive amount of those jobs are related to (...) just shuffling information around. You have so many manual task points -- from the point where you contact the liner and say you want to book a container until it's actually delivered. And all of this information or handling points (...) can be automated. //

He went on to explain that approximately 100,000 people are employed in the shipping industry to manage these "information points" manually, including the documentation of the bookings. But with the introduction of automated freight orders, such as e-bill of ladings, these jobs could easily be reduced, if not made obsolete. He added:

// And the interesting thing is that eliminating tens of thousands of documentation jobs is probably going to be relatively painless [in Norway], except for the poor guys who lose their jobs because they're located in places like India. //

Taking note of the point made earlier about automating the supply chain, one should also consider the office side of shipping. Firstly, automation will change the way in which conventional shipowners conduct their business, which will in turn have an effect on conditions on board a ship. Secondly, with the work of officers focusing more and more on digitalized tasks performed on a screen, rather than in the engine room or on the bridge, it is conceivable that blockchain technologies, such as the e-bill of lading, may become part of the captain's documentation and administrative tasks going forward.

E.2 DEVELOPMENT TIME FRAME

If all developments are driven by good business models, then business models will determine the speed of adoption. Norwegian business models are driving both total transport systems, including autonomous ships,

and increased digitalization in conventional shipping. In the following paragraphs, the report will lay out the time frame for the development of each trend presented by the stakeholders who were consulted for this Norwegian case.

⁴⁹ For example, the Liberian Flag State is taking steps to digitalize many of its services.

⁵⁰ See, for example, Stena Shipping's collaboration with the Massachusetts Institute of Technology (MIT) Sloan: Stena Bulk, 'Stena Bulk's Successful Mit Sloan Project with Blockchain', 2017, <https://www.stenabulk.com/press-and-news/press-releases/stena-bulks-successful-mit-sloan-project-blockchain>.

Development time frame for autonomous ships

The world's first autonomous container ship, the Yara Birkeland, is currently being built at the VARD Braila shipyard in Romania. The contract for the propulsion system was signed with Brunvoll in February 2019. The Yara Birkeland is expected to be in operation within three to five years. Testing of the autonomous system began in 2018, using a moveable container bridge with a captain and crew. The yard is expected to deliver the hull in 2019, and will conduct autonomous testing at sea by remote control and with a crew on board. From 2020, the plan is to gradually de-man and shift from remote control to autonomous operations. Experts consulted expect that the Yara will be in autonomous operation, with supervision, within three to five years. As it prepares to become operational, the Yara Birkeland will have to be classified. As it is the first ship of its kind, the decisions from the classification societies will impact the timeline of putting such ships into service.

Experts have anticipated that similar total transport systems involving autonomous vessels will be unveiled in the next few years, in parallel with the Yara Birkeland. Projects re-thinking the entire supply chain may be widely implemented by manufacturers looking for new solutions to their supply chain transportation needs. Examples of such cases are being tested along the autonomous Trondheim Fjord test-bed, as described heretofore. Such projects will create new maritime routes, and thus not replace existing seafaring jobs, but create a limited number of short-term shipboard positions, and significantly more jobs in shore-based control centres.

One technical expert suggested that, in the interim period, seafaring jobs would still be available on board smaller vessels operating in territorial waters over shorter routes, but that after approximately 8 to 10 years, these positions would become obsolete.

One of the first places experts expect to see autonomous systems replace existing crews is on short-range inland ferries. As previously noted, electrical propulsion ferries fitted with auto-crossing technology are being introduced, which will free captains from their primary navigational task. The effect on crew tasks related to passenger services, safety and fire hazards remain to be seen after 2019. As battery power increases for short inland routes, longer range ferries and cruise ships could then be spheres for autonomous innovation.

In the case of the autonomous ship, new business models made possible by technological innovation are driving changes. The companies behind these changes are not necessarily shipowners or close associates of the industry, but manufacturers like the fertilizer manufacturer, Yara. They regard the development of a new transport system as part of their long-term planning, and investment in such a project is thus very dependent on the budget for long-term internal improvements in the company.

Development time frame for digitalization in ships

Digitization in conventional merchant cargo ships in Norway and beyond is expected to continue to intensify in the coming decades. As data becomes the new "oil" of the global economy, shipping companies will likely join other sectors to optimize their business processes via increased data analytics.

The first step will be the enhancement of sensor-based monitoring and navigation, which are beginning to be implemented on board some merchant ships. The next step will be further automation in the engine department, through advanced decision-support systems. A part of the automation of the engine will include an increased focus on redundancy in engine operating and monitoring systems.

The time frame for engine developments is very dependent on the types of alternative fuels that are coming on the market as alternatives to heavy fuel, in line with recent IMO emissions regulations. It was suggested that this would not affect long-haul shipping as ships performing this kind of voyages are unlikely to be battery-powered. But even the use of alternative fuel sources does not appear to be problem-free as yet. LNG is perhaps an exception on account of its technical and safety viability.

When considering changes within the current fleet, it is important to note that the speed of digitalization will be depend upon the return on investment on existing ships in operation and the general upswings and downturns in the global financial market. According to a report compiled by the UNCTAD in 2010, a new dry bulk ship - Handysize, 30,000 DWT, costs approximately USD 25 million⁵¹. Given this steep price, the investment needs to make sense in terms of the company's other operational expenses and the general financial climate in an industry that is deeply dependent on the global financial market and vulnerable to its fluctuations.

These factors will determine the time frame for new ships to be built, with varying degrees of autonomous technology on board, to be bought and inserted into the supply chain. The average lifespan of a merchant cargo ship is 22 years, according to this study's experts, and 15 for a passenger ferry on short routes. When those ships have returned their investment and are old enough to be considered for scrapping, new, more innovative designs, for example, fitted with an electric propulsion, may be integrated into marine traffic. However, questions remain about how far battery-powered propulsion systems can travel. This will have an impact on which routes and ship types would be considered for this type of propulsion.

⁵¹ UNCTAD, *Review of Maritime Transport 2010* (New York: United Nations, 2011).

Yara Birkeland

- fully electric autonomous container ship

Project initiator:
Yara

Technical coordination:
KONGSBERG

Operation starting in:
2020
(expected)



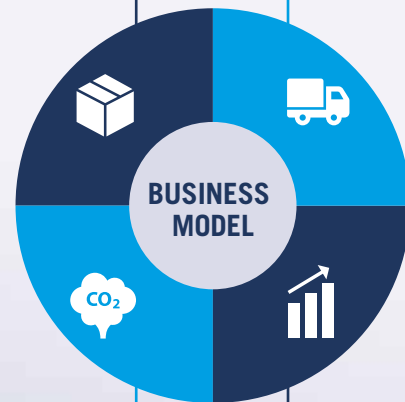
Estimated total cost:
NOK 400 million
= USD 46 million*

Ship hull cost:
NOK 250 million
= USD 29 million*

* At the March 2019 exchange rate.

Transport of manufacturer's product (fertiliser)

Substitute of 40,000 truckloads on difficult roads yearly



Reduce pollutant emissions
- enabling state subsidies
(NOK 133.6 million)

Increase transport efficiency



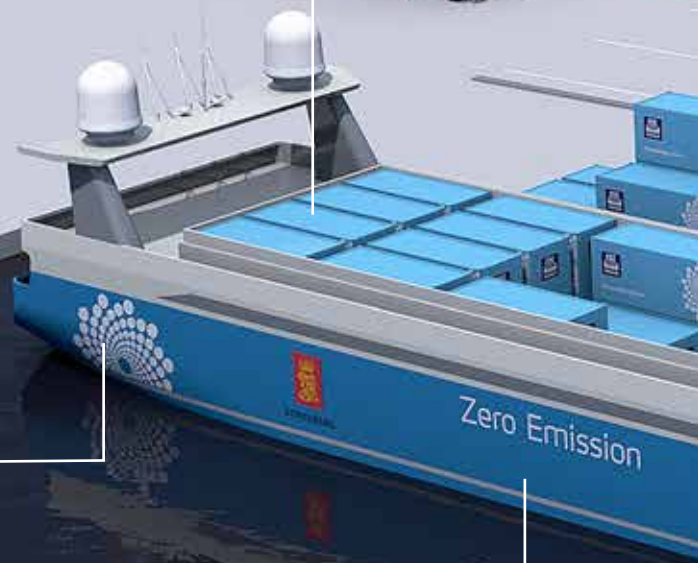
Load capacity:
120 TEU



Propulsion:
Azipull pods
2 x 1200 KW
Tunnel thrusters
2 x 700 KW



Width: **15 meters**
Length: **80 meters**



FACTORS FOR ADOPTING THE TECHNOLOGY



ECONOMIC BENEFITS

Economic incentives exist by reducing the 40,000 truckloads per year. Total fuel is reduced and more parts of the transport system become more flexible (total transport system integration).



REGULATION AND GOVERNANCE

Norwegian authorities are supporting the project, for example, by subsidizing it by one third due to the fact that it leads to a reduction in CO₂ emissions, or by creating test areas for autonomous ships.



SOCIAL ACCEPTANCE

Norwegian society is very open to new technology. Technology is seen as bringing prosperity to society as a whole.



KNOWLEDGE AND SKILLS

The maritime cluster has the knowledge to develop the technological solution, operate and maintain it. Maritime training programmes are changing as a result of novel technologies.



LABOUR MARKET DYNAMICS

The cost of labour in Norway is one of the highest in the world, and thus incentives to economize on labour exist. Moving seafarers to shore-based positions where digital skills are needed is expected.



TECHNOLOGY FEASIBILITY

Currently, the technology is being developed and applied for this specific purpose. Several challenges still subsist, but full technology feasibility is expected to happen in near future.



© Yara and Kongsberg Maritime



Designed to operate first with crew, then with no crew



Service speed: 6 knots



Batteries:
Capacity 7 MWh



Deadweight:
3 200 mt

FUTURE OF SEAFARING: SEAFARER 4.0



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F. FUTURE OF SEAFARING: SEAFARER 4.0

As has been stated throughout this report, the belief that autonomous ships will completely revolutionize shipping and seafaring is not a valid proposition as regards the majority of shipping operations over the globe. The first autonomous ships will not replace existing cargo ships, but instead will solve very narrow transportation challenges, and might even

create more jobs for seafarers, albeit with altered tasks. For that reason, it is key that attention is directed toward the increasing “digitalization” that is changing the tasks and skills of seafarers. This study characterizes this development as the influence of Industry 4.0 on the seafaring profession, or “Seafaring 4.0”.

F.1 REMOTE SEAFARING

The labour representatives consulted for this report did not seem to be concerned that seafarers would become obsolete, but identified a trend of changing tasks. Instead of being hostile towards technological innovation itself, the interlocutors consulted noted that a common question was, “What can technology do for us?” With the Yara Birkeland as a case in point, this study points out that autonomous ships will require tasks that include remote control of the ship, monitoring of its operations, such as autonomous systems in bridge, engine and sensors systems and integration of data, and also tasks related to intervention in case of an accident or emergency.

Shore control centres will have different profiles and responsibilities, covering both logistic performance from the manufacturer’s perspective, technical operations and performance, and safety of ship and waterways from the Coastal Administration’s perspective. For seafarers, the tasks performed at such control centres will require professional backgrounds from different parts of the maritime industry, and the ability to mix maritime experience with digital system skills and software engineering. This is why we term this new potential profile “remote seafaring” (or “e-faring”). Skills needed for future control centre operators at shore are still in the process of being defined, but experts have noted that a basic understanding of software programmes and data fluency, and the ability to operate digital control systems will be essential.

Seafarers working as officers on ships with advanced digitalized applications reported that a shift to remote-controlling vessels ashore could pose an interesting challenge to their skills. A captain, who was interviewed for this study, explained that he thought it would be “fun” to control the vessel “like a computer game”, adding that earlier in his career, he liked to challenge himself by navigating at high speed solely by radar during bad visibility. He hinted that his

gaming skills played a role in his choice of a seafaring career, but noted that some colleagues chose a seafaring career for other reasons.

While idiosyncratic personality traits certainly play a role in career choices, it is important to note that Norwegian non-seafaring salaries on land are comparable to Norwegian officer salaries at sea. In other words, there is no economic incentive for choosing an international seafaring career for Norwegian seafarers who are officers. This cannot be said for seafarers from major seafarer-providing countries like the Philippines, where the discrepancy between most land-based salaries and seafaring salaries are substantial⁵².

For these reasons, and particularly since the liberalization of Flag State regulations in the nineteen eighties, Norwegian seafarers have shown a growing interest in seafaring jobs within Norwegian territorial waters, such as on ferries, cruise ships and local shipping, in addition to shore-based shipping positions. “Remote seafaring”, as we have termed it, will thus not be regarded as involving radical change in the lives of Norwegian seafarers as might be the case for other nationalities. Such a scenario raises questions about how these “remote seafarers” may be unionized moving forward. This study will return to these social themes shortly.

One point to be highlighted, however, is that a subset of Norwegian seafaring jobs is directly vulnerable to the introduction of autonomous ships: seafarers working in short-range passenger ferries. Our data suggests that the jobs most at risk of becoming obsolete are short-range ferry captains and engineers. As the engine becomes electric and the operational processes more simple, less or no on board maintenance will be needed. Because the targeted routes are relatively short, engine maintenance and corrections will be able to be done in port. As a result, the engineer may work on several ferries from the port,

⁵² ILO, *The Global Seafarer*, 57-62.

potentially together with engine ratings or technicians. The captain's work may move to shore-based control centres, where the ferry may be remote-controlled and/or monitored during autonomous operations. This will remove the need for the captain to be on board the vessel, and will likely change her or his required skill-set.

As with other autonomous ships, "remote seafaring" may entail the supervision of several ships at once. For autonomous ferries, this would de facto indicate a loss of jobs, whereas control centres focused on new routes for autonomous ships will create new jobs, despite involving the supervision of multiple vessels simultaneously.

One debate among technical experts was whether shore-based control centres would depend upon conventional seafaring skills or not. The seafarers consulted often referred to their hands-on experience and "gut feeling" when navigating, and argued that the feeling for the ship and its surroundings was crucial for safe navigation. But they were also cognizant of subtle shifts in the skills required to do their job. In the example of the shift between on-site and remote navigation, one captain explained that when docking, he would stand on the bridge-wing where he could keep an eye on how close he was to the quay, carefully navigating his large ferry into place with the stern and bow thrusters.

But when the ferry was rebuilt, the bridge wings were removed and sensors were installed. Now he only had the sensors and his screen, placed mid-bridge, to rely upon for safe and accurate docking. This change involved a shift in the requisite skills now needed for the operation -- from "a feel" for the bow and stern thrusters and faith in his ability to estimate the distance to the quay with his own eyes, to understanding the digital representation of these things on his screen.

Docking a ship from a shore-based control centre would further shift skills from hands-on and on-site seamanship to something more akin to gaming skills. As if to confirm this shift, one chief engineer consulted affirmed that he favoured applicants with electrical engineering backgrounds and explicit IT skills over applicants with strong mechanical

engineering skills. Engine-related tasks, he explained, were becoming more and more digital and needed someone who could handle the digital tasks, even though they might not be "able to tighten a bolt."

Ratings: ticket sales, catering, safety personnel and shore-based maintenance?

It is important to mention the changing role of ratings in Norwegian shipping. As with the general trend for seafaring labour from Western countries, the employment of Norwegian officers and ratings has been on a steep decline since the liberalization of Flag State regulations in the 1980s. As noted previously, high salaries both for Norwegian seafarers and for Norwegians in general have inspired many Norwegian seafarers to abandon an international seafaring career. Instead, some have chosen to work on inland ferries and this subsector is also attractive to Norwegian seafarers with a limited education.

Automated inland passenger ferries was a scenario discussed with the technical experts, in which one issue - the safety of the passengers on board - was addressed. The potential solution suggested was to keep a designated safety crew member on board in case of fire, or the need for evacuation. This would not necessarily require a highly trained navigational or engineering officer, but could be managed by a rating. In addition, passenger services like ticket collecting, food and beverage sales could continue to be carried out by ratings.

Some of these arguments are also relevant for maintenance work. On board traditional ships, much of the maintenance is carried out while the ship is at sea. Salt water has a nefarious effect on the hull of the ship and deck ratings spend a significant amount of their work hours on chipping rust and painting tasks. In addition, an engine run on heavy fuel requires regular monitoring, adjusting and small repairs while in operation. Since autonomous ships in Norway are set to operate along short routes - Yara's planned itineraries are 7 nautical miles and 30 nautical miles respectively - repairs and maintenance can be carried out in port. This scenario means the small number of Norwegian ratings working within territorial waters would have strong job security.

F.2 EDUCATING THE NORWEGIAN SEAFARER 4.0

Taking into account the above-mentioned information, it is necessary to consider what changes are expected in terms of education. The Norwegian seafarer may be especially well equipped to take advantage of these changes in shipping, as the maritime educational system already includes computer literacy, software understanding and alternative degree programmes that combine digital skills with classical maritime competencies.

Some maritime educational institutions in Norway are working with technical universities, bringing students

and the faculty of maritime and technical studies closer together. As these schools transition to universities and introduce research-based education, maritime education becomes more academic in character⁵³. This transition is a way to integrate maritime and technical skills in the Norwegian education system. In terms of education, this initiative was the only public response our researchers observed to the anticipated and combined need for maritime and AI, or at least digital skills in the maritime industrial sector.

⁵³ We differentiate between maritime "educational institutions" or "schools" and universities to make the structural difference clear. Since the introduction of the Bologna Process in 1999, educational programmes across Europe have become streamlined and translatable across national borders. This means that vocational schools have also undergone an academization, in which professional certificates are being translated into bachelor and master's degrees. For more on the Bologna Process in Norway, see <http://www.ehea.info/cid101576/norway.html>. Retrieved on 30 January 2018.

Future seafarers’ skills and competencies are still uncertain

Anticipating the forthcoming developments in the maritime industry for Norwegian seafarers is challenging, even for the educators involved. Educators consulted for this report explained that there were currently developing three distinct specializations within the same institution: nautical studies, maritime engineering and shipping logistics. Students specialize in one field but can also study two other specializations as well. Actual cross-courses were discussed but have not yet been developed. Educators were also considering a joint specialization on “maritime computer science”, which could reintroduce the “dual license” in another form, namely, a dual maritime and computer science license. But when pressed for specifics about the skills needed, they admitted not having information on this matter.⁵⁴

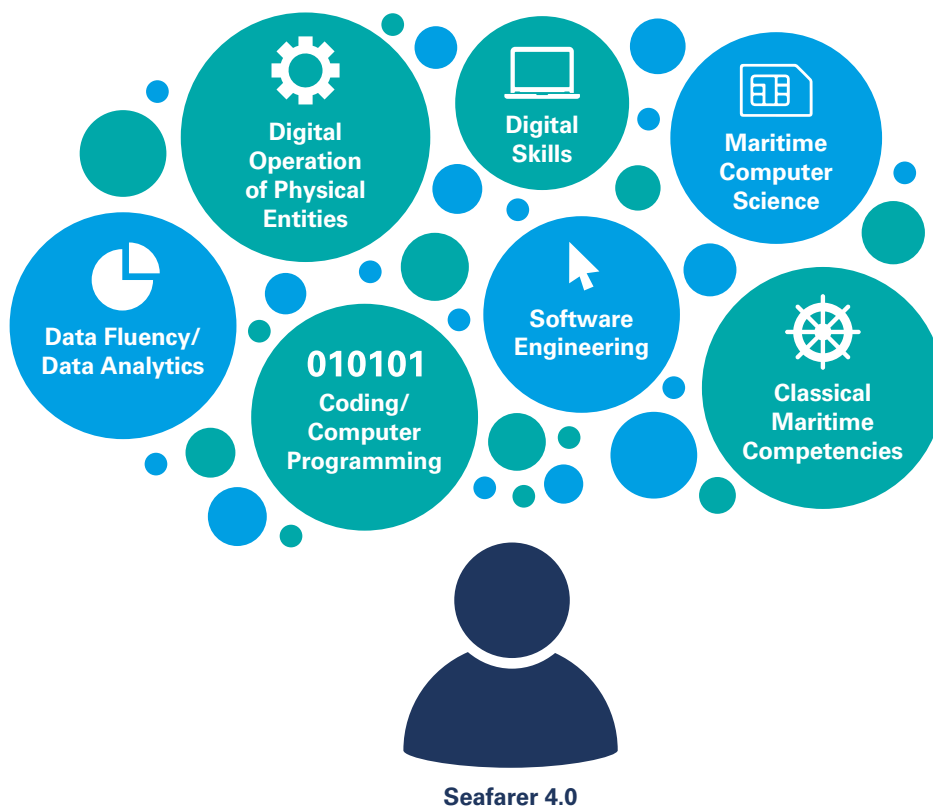
One major point that was raised was the lack of faculty personnel with qualified credentials for teaching at the university level in Norway. As maritime schools become accredited as universities they must attract a faculty with at least a Ph.D. degree to teach students studying for a Masters degree. Seafarers with Ph.D. degrees, or similar qualifications, are hard to find, and the number of teachers

at the professor level with seafaring expertise in Norway is very small. Experienced Norwegian officers have generally been educated at vocational schools, whose programmes have no direct correlation to research-based knowledge generation and for the education of maritime academics who will educate the seafarer of the future, or the Seafarer 4.0.

Although Norway has made considerable progress in this area, it is still only developing the educators to teach the next generation of seafarers. A newly started Ph.D. programme in nautical operations is the first of its kind in Norway, and is a joint endeavour between four institutions, with the aim of generating research staff in the form of Ph.D. candidates and beyond. They are to train students taking a series of new master’s degrees in maritime and nautical studies.

The concrete skills needed for Seafarers 4.0 are still poorly defined, as the experts consulted highlighted. All the skills required, from introducing a manned remote-controlled ship like the Yara Birkeland in its first phase to an autonomous and unmanned ship, are still not clearly articulated. Tasks and skill sets will be developed for each of these steps in time, and will be concentrated in the fields of shipping logistics, digital operation of physical entities, or software engineering and computer science (Figure 6).

FIGURE 6 Seafarer 4.0 and related competencies



⁵⁴ Another important issue – the IMO, WMU and the Norwegian Government have been actively promoting women’s entry into the maritime industry and introducing measures to promote women to senior positions in the industry. See the Hannah Aba Aggrey, ‘Women in the Maritime Industry : A Review of Female Participation and Their Role in Maritime Education and Training in the 21st Century’ (Master Thesis, World Maritime University, 2000). Indeed, for “World Maritime Day 2019” on 27 September, the IMO selected the theme, “Empowering Women in the Maritime Industry” (World Maritime News, ‘IMO: World Maritime Day 2019 to Focus on Women’, 2018, <https://worldmaritimeneews.com/archives/256582/imo-world-maritime-day-2019-to-focus-on-women/>). See also, the WMU Empowering Women in the Maritime Community Conference, <https://www.wmu.se/news/way-forward-conclusions-wmu-empowering-women-maritime-community-conference>.

According to the seafarers interviewed, the education is very old fashioned and the skills they mastered was learned on board ships as cadets. In an interview with a captain, he admitted that he already knew the information provided at courses he currently attended: his ship was equipped with the newest technology that he had mastered while on the job. These trends point to the fact that maritime education institutions may not be

the primary institutions to equip students with skills on the cutting edge of technological development. Rather the skills and expertise required to use technologies and applications already installed on ships could be introduced into the school curriculum to a greater extent so that such knowledge could be imparted early, not after graduation when students are working on board a ship.

F.3 THE SOCIAL LIFE OF NORWEGIAN SEAFARERS

// ...let's say someone is away at sea for five years, ... it's really difficult to be away from your children for that length of time. I'm not getting rich by working on the tanker. It's like, it's a decent Norwegian salary. I can earn the same if I go and work for [the union], I'll earn the same pay. But if you're a Filipino seafarer, you can never, ever get the same pay working in the Philippines, especially if you're a captain or an officer. [Economic disparities in the Philippines means that many opt for seafaring as a profession to earn a good living.] And I think therefore that the threshold of quitting or stopping is lower. You can always get a ferry job or find office-based work. //

The above quote is an excerpt from an interview with a Norwegian seafaring officer. He highlights a common theme that is present through all of the report: work-life balance is important and the Norwegian public welfare system is set up in such a way as to make such prioritization possible and even profitable for the State. This basic tenet informs Norwegian seafarers, technical experts, educators, developers or union representatives and is fundamental to understanding Norwegian Seafaring 4.0.

The value of work-life balance and faith in the Norwegian social State was reflected in the interlocutors' opinions about career paths and job security, their prioritizations and values in terms of personal happiness and family life, their perceptions of technical development as a source of common good, and even a perhaps overzealous optimism in the future of seafaring.

In the following paragraphs, we provide some insight into what it means to be a Norwegian seafarer today, in terms of their motivations for pursuing a career at sea, what they find positive and the challenges involved, and how the specific Norwegian context plays into their position within Seafaring 4.0.

Trust in the norwegian state, seafaring 4.0 and the definition of a good life

// The Norwegian society is quite democratic. It's a very short distance between the seafarers, the manufacturers and the shipowners. So, if you have something on board that doesn't work you will immediately inform the relevant person responsible. That gives us a competitive edge because we have a very democratic structure. You're allowed to say what you think in Norway. //

The above quote is taken from an interview with a union representative, but it is a shared sentiment in the Norwegian maritime sector. Norwegians see themselves as part of an equitable society, a value that is manifested in the idea and practice that everyone's opinion counts. For this reason, even the "simple" seafarer can "say something" to the shipowner or the technology developer. Practice-oriented criticism is valued for its contribution to policy and technology.

The interlocutor quoted above explained that, because of clear lines of communication in Norway, practitioners and developers from across sectors could learn from one another by sharing experiences and lessons learned. Similarly, other members of the Norwegian Maritime Cluster explained that their ability to speak and support each other across sectors was what made them a strong collective for the development of new technology.

These considerations are embedded in the way personal and family lives are structured as well. The history of seafaring in Norway is compelling and in most interviews interlocutors say that, "We've always been a seafaring nation. Everybody has an uncle, a grandfather or neighbour who was a seafarer". But social welfare is equally important and social isolation is a concern. Indeed, a seafarer who was interviewed for the report, warned that, "You have to remember this: today, more people are going ashore in a straitjacket than on a stretcher." In addition to the personal challenges of social isolation, family struggles connected to work life at sea take a heavy toll, a cost that Norwegian seafarers appear to be less and less willing to pay.

“ It tears you apart... You can try to explain to a five-year old why you’re away all the time... [My neighbour], he’s always been very, very focused ... but now he’s actually considering anything on shore, just to get back home ... his kids, they start to count down when he leaves...If you’re a guy, you have to have a really tough and supporting wife who supports your choice. [You used to write] a letter to a girlfriend and she waited a year. They won’t do that today. If you’re away for two months, they’ve forgotten about you when you come back. ”

The seafarer cited above was conversing with a younger colleague who works on board an international merchant tanker. He wondered how he will feel when he had children, but explained that he never felt he was missing home much. His older colleague quipped, “Yeah, until you come home and your kid doesn’t recognize you.” These are common themes among international merchant seafarers, regardless of where they are from. Because of the social challenges of being at sea and the opportunities that Norwegians have on land, the existential drive to work at sea to provide for the family, a norm that is common among seafarers from other countries⁵⁵, is not a common aspiration among the Norwegians interviewed. One seafarer explained it this way:

“ You need to be happy with your job...you need to have the money to live and do what you want. But, of course, we are very lucky here in Norway and Europe that we can choose. (...) I think technology may open up new jobs and it could be that industry is going down a [different] path. [I might] say, ‘Hey, I want to do something completely different... this is not for me anymore’....so maybe [some people] will quit and do something else. ”

This seafarer regarded working at sea not as a means to provide for himself and his family, although his work certainly fulfilled this goal, but more as a choice made to live the ‘good’ life as an individual. If this choice would not fulfil the individual’s definition of a good life, he understood that Norway would give him the opportunity to make new choices that would guide him down a path better suited to his aspirations.

Re-shoring: bringing norwegian seafarers home

With headlines such as “After the Robot Revolution, What Will Be Left for Our Children to Do?” (2016)⁵⁶, prophesying the replacement of about 40 per cent of jobs by robots, it is not surprising that workers may feel uneasy about the future

for themselves and their children. Therefore it is perhaps even more surprising that in a country where labour is known to be expensive, new technologies were seen as benefiting workers. One union representative our researchers interviewed explained,

“ As for us, living in Norway, I’m not asking ‘What will digitalization do with me?’ I will ask, ‘What can the digitalization do for me?’ Because living in a high-cost country, competing in the global market, we need to make the most of it. What digitalization can give us is an ability to operate in a less costly manner, more safely, more efficiently. ”

Instead of seeing the introduction of new technologies as a threat to his livelihood, he seemed to be suggesting that workers and developers needed to work together to create an industry that was able to compete on a global market without compromising on basic tenets of the Norwegian public welfare system. In order for this to be possible, the choices that the seafarer, who was quoted earlier, had at his disposal need to be informed by a robust social policy in terms of equity in the labour market and a robust educational vision.

In an industry where seafarers can spend months away from home and their families and expertise has been systematically outsourced to countries with lower labour costs, a clear movement appears to be underway to equip Norwegian seafarers with the skills needed for Seafaring 4.0. This movement would generate expertise in Norway and it would bolster Norwegian family life. In that regard, the research shows a clear re-shoring movement is underway that would create the opportunities for introducing further automation and technology into the maritime industry in Norway.

Many of these stakeholders spoke about bringing Norwegian seafarers “home”.⁵⁷ One educator explained:

“ We are now changing the maritime training system. We are imparting all our nautical guys with knowledge in computer science, project management, machine engineering on a high level... We are not giving this education to you for your first job – this is for your second job, when you’re going back on land. (...) then you’ll have a master’s degree. And if the maritime industry can take the same person and reinsert him into the same system, then the maritime industry in Norway can pick and choose from its own national companies. ”

As described earlier, the changes in the Norwegian education system in recent years as part of the “Bologna Process” has meant that former vocational schools have been required to

⁵⁵ Gunnar M. Lamvik, ‘The Filipino Seafarer: A Life Between Sacrifice and Shopping’, *Anthropology in Action* 19, no. 1 (1 January 2012), <https://doi.org/10.3167/aia.2012.190104>; S. E. Roberts, B. Jaremin, and K. Lloyd, ‘High-Risk Occupations for Suicide’, *Psychological Medicine* 43, no. 6 (June 2013): 1231–40, <https://doi.org/10.1017/S0033291712002024>; Helen Sampson, *International Seafarers and Transnationalism in the Twenty-First Century*, 1. pbk ed, New Ethnographies (Manchester: Manchester Univ. Press, 2014).

⁵⁶ The Guardian, ‘After the Robot Revolution, What Will Be Left for Our Children to Do?’, 2016, <https://www.theguardian.com/careers/2016/may/11/robot-jobs-automated-work>.

⁵⁷ The authors of this study are not aware of any formal public policy in the area.

streamline their courses with other European universities, offer research-based teaching and award bachelor, masters, and Ph.D. degrees. The educators interviewed saw this change as part of a strategic move to secure and promote Norway's maritime future.

The introduction of new technologies and the skills point toward a labour market in which Norwegian seafaring expertise would go hand-in-hand with new technologies. The educators explained that the public sector was ready to provide the financial support to make changes in the educational system that would address this need. As a result, Norwegians could 'corner the market' in regard to this skill set, and thus compete on the global market. This in turn would allow Norwegian employers to choose Norwegian labour over foreign labour.

Misplaced optimism

Such assertions depicting how labour needs and technological developments meet in perfect synergy may seem unrealistic. To some extent this may be the case. However, seafarers have expressed an optimism about the future that did not always go hand-in hand with emerging technological developments and the logics informing them. Certainly technological innovation can be disruptive and lead to sudden change.

For example, one notion among an interviewee was that "the threshold for fully autonomous ships [would] be higher in the passenger ferry market". One ferry captain asked rhetorically,

// If you're on a ferry, a cruise ship, transporting passengers, would you be comfortable on board a ferry and know that there's no crew on board? I don't think I would have allowed that ferry to have no crew on board. //

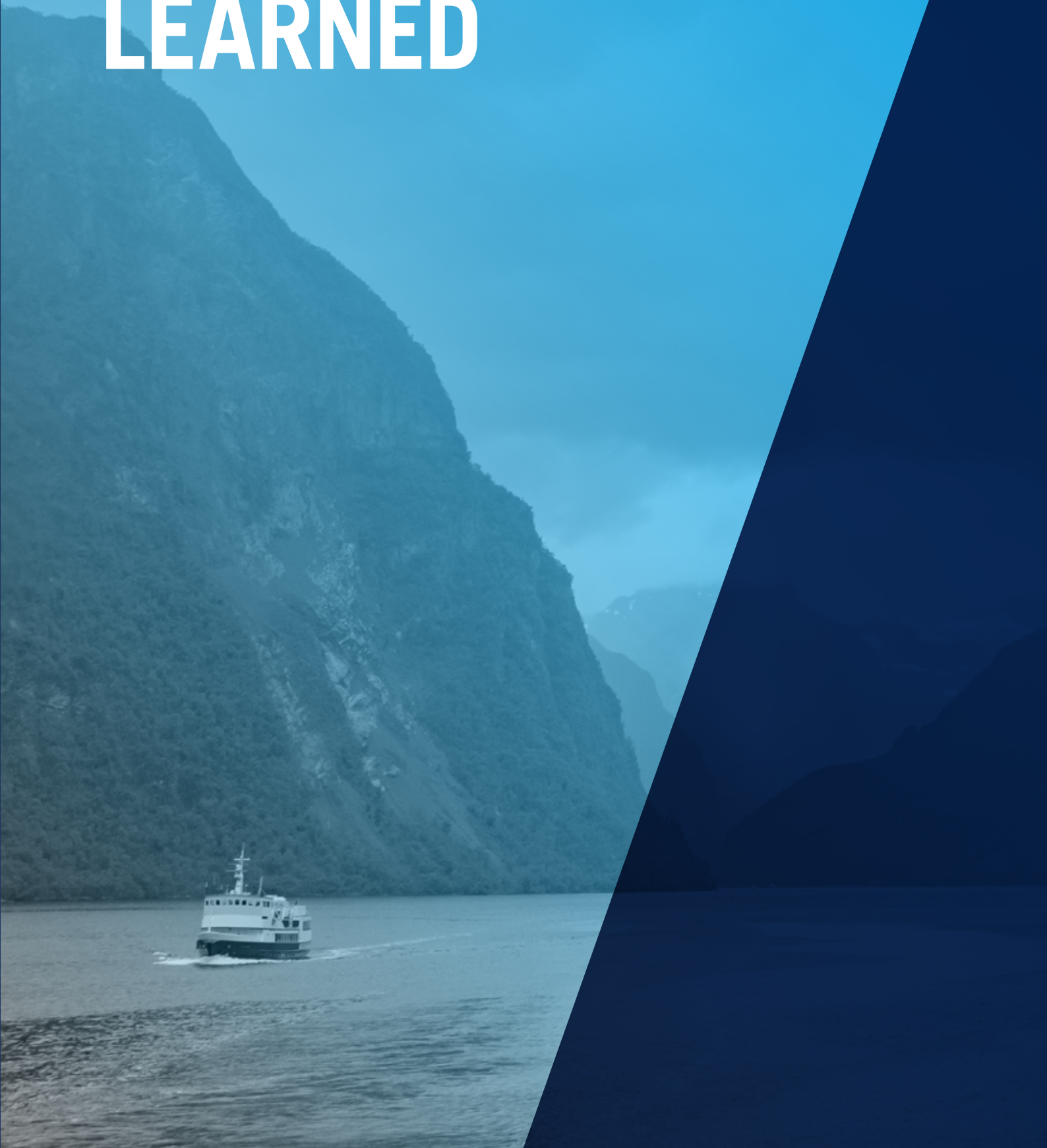
However, this does not seem to fit with the very concrete plans for battery-powered ferries, and the implementation of auto-crossing and auto-docking. The step towards having an unmanned vessel for these routes seemed to be difficult to imagine, despite quite compelling evidence that manufacturers were currently taking these steps, for example Yara, as well as Rolls Royce in collaboration with the county authority Sør-Trøndelag Fylkeskommune.

We see another example of "misplaced optimism" among seafarers with regard to how they link their current tasks to those that can or cannot be automated. One seafarer explained,

// But there's also the operation on board a chemical tanker – it's one of the most complex things you can do. The ship that I am on has 47 different tanks which can carry 47 different products, and some products need to have heat monitoring that cannot exceed 25 degrees. You have to have cooling; for some products, you have to have heating. It's very complex, and it's like, yeah, if you have autonomous ships and cut back the crew, there also has to be people to look after the cargo – and who will that be? //

The complexity regarding the tasks that this officer describes is precisely the kind of monitoring work that is made for autonomous systems. Computers are becoming better than human beings at handling large amounts of complex data. The officer may remain on board for many years to come, but monitoring tasks like the one described above can be performed by current technology.

CONCLUSIONS AND LESSONS LEARNED



CONCLUSIONS AND LESSONS LEARNED

A hiatus exists between the understanding of the effects of new technologies and of automation in the Norwegian maritime transport sector among seafarers and the rest of the Norwegian maritime cluster. Seafarers do not believe the time frames cited for the introduction of autonomous operations, hold a sceptical attitude toward the systems' actual operations at sea, and remained certain that their work would be needed well into the future. On the other hand, technical experts, in particular, stressed that the introduction would be rapid, that the systems performed well in tests and that the introduction of autonomous operations at sea had immense potential.

This report underscores two findings:

Firstly, the autonomous container ship is coming to Norway within the next five years and more such vessels will follow. They will, however, travel on short-range new nautical routes and form part of the total transport systems, but will not replace conventional merchant ships. Autonomous container ships are currently limited to regional test beds and national territorial waters, governed by national regulation.

Meanwhile, the conventional merchant fleet will intensify its current "digitalization" trend of bridge and engine, transforming officers' tasks so that they correspond more to senior managerial responsibilities and involving monitoring and optimization of digital systems; and it will put greater emphasis on the integration of systems and data. Ratings will still be needed for the valuable maintenance work they perform on most ships, as the fleet will generally be retrofitted and only slowly replaced.

Secondly, the introduction of autonomous ships and the reframing of supply chains represent a paradigm shift in maritime transport. This trend has the potential to restructure parts of the maritime trade, as shipping is transformed from a transportation service to part of the manufacturer's internal logistics. This is happening in very specific places in Norway now, and might be a model to replicate in similar cases and contexts were it to be successful.

Seafarers working on short-range inland ferries in Norway are the only group at risk of being directly affected by the introduction of autonomous operations. Plans are in place to employ electrically-powered ferries at the next cycle of replacements at some destinations, and with technology, such as auto-crossing, ready, short-range ferries can plausibly operate autonomously. In this scenario, the captain and engineer on board will be superfluous, as one captain at a shore-control centre can monitor and operate several ferries, and a group of engineers can provide maintenance on several ferries. Ratings may remain on board for service and safety tasks.

Seafarers in Norway did not understand the paradigm shift taking place in maritime transportation work, but this study has argued that this shift will have positive implications for Norwegian seafarers, as it points toward a new form of employment for seafarers - "remote seafaring". New routes served by autonomous ships will need a small number of shipboard crew members for test and emergency operations, but a large number of shore control centre operators will be required. In terms of education, Norwegian seafarers will need to mix a maritime background with digital skills in either data analytics, digital operation or software engineering, qualifications that will put them on track for these new seafaring positions.

A shift toward remote seafaring using highly trained workers in shore control centres represent an opportunity for Norwegian seafarers to reverse the offshoring of seafaring labour and bring Norwegian seafarers back to Norwegian vessels and maritime workplaces. As the competition regarding salaries is not relevant on land, Norwegian seafarers are not more expensive, but will have a higher and more specialized education, in addition to the benefit of speaking the native language.

This development has the potential both to be a re-shoring movement in seafaring labour, and to position Norway and the Norwegian maritime cluster as the place to go for tailor-made maritime transportation systems. Such knowledge will be in great demand as the maritime transportation sector repositions itself within the Industry 4.0 regime.

The Norwegian case provides information on the pace of technical development, the innovative nature of the first-generation autonomous container ships and the potential opportunities for future seafarers. Moreover, Norway is a bellwether in both the technical development of ships and systems and in the education of its seafarers.

This report has only focused on Norwegian seafarers. It may be worth considering countries where conditions are similar to those in Norway in terms of geography, educational potential, technical and maritime expertise and local business stakeholders, with tailor-made transportation needs. They might be prime testing grounds for similar initiatives.

It appears clear that for years to come, conventional merchant ships will continue to serve the long-haul trade. Such ships will be impacted more by the incremental "digitalization" of their operations, which will be introduced unevenly in the global fleet. The fleet of tomorrow is transforming as autonomous ships take to the seas, but as such, wide disparity in technology between ships is already the norm.

LESSONS LEARNED

- Autonomous ships will not replace conventional cargo ships and render conventional seafarers obsolete. Autonomous ships will become part of local transport systems, creating new nautical routes as alternatives to other transportation modes.
- An increase in the current “digitalization” of the conventional fleet will continue and transform seafarers’ tasks into more digital ones, especially in operations monitoring and system management, as well as with respect to tasks that involve less human intervention and involvement.
- In the next five years, we can expect to see more plans for autonomous ships and to form a part of total transportation systems.
- Seafarers working in short-range inland ferries in Norway are at risk of losing their jobs as a result of autonomous operations. Captains and engineers are at special risk of being moved to shore-based positions, which will limit the need for personnel on board. Technology enabling autonomous operations is already bringing change to inland ferries.
- The seafarer of the future will benefit from combining an understanding of maritime issues with digital skills in three general domains:
 - Data fluency and an ability to interpret and analyse big data
 - Digital operation of physical entities
 - Software engineering of fundamental programmes and systems.

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World Maritime University
PO Box 500
S-201 24 Malmö
Sweden
www.wmu.se

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