Maritime in the 21st century:

2000-2030

The state of play, a brief history, a roadmap, and scenarios

Focusing on the Baltic Sea and Ro-Ro Shipping

CELINE

ECOPRODIGI

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EXECUTIVE SUMMARY

ECOPRODIGI is an initiative of the EU-Interreg Baltic Sea Programme, whose mission is to improve and promote the eco-efficiency of shipping and maritime operations. This report is a product of the work package 4 (WP4); a foresight exercise, whose mandate is to provide a roadmap for the future of maritime operations on the Baltic Sea with a focus on Ro-Ro shipping. A sister publication exists that provides a policy-innovation roadmap for shipyards, entitled "Road to Shipyard 4.0" published by ECOPRODIGI.

This report is a product of inter-disciplinary collaboration. At the core of the team are the consortium members. Early drafts were validated through consultation with experts, and results were then summarised and validated together with wider industry and policy actors through surveys. More information about the methodology is found in the appendix.

The potential users of this roadmap include a wide variety of stakeholders. Policy makers can use it as an agenda-setting reference for promoting and championing eco-efficient policies, regulations, and standards. Industry stakeholders can use it to check against their own strategies for coherence. Researchers can use it to anticipate questions that might be of particular relevance over the next decade. Technology developers can use it to benchmark against their own expectations for technology development. In all, this roadmap can be a starting point for discussion so that all stakeholders can move together into the future, forward, by sharing the expectations for development in order to coordinate action to enact eco-efficiency in the Baltic Sea and beyond.

The report is organised as follows. The introduction will lay out the current state-of-play of eco-efficiency and the zeitgeist of the current situation on maritime that we find ourselves in, in 2020. The next section will provide some historical context looking back to 2010 and 2000 to trace the trajectory and developmental course on which we are.

The core contribution of this report is the Maritime Operations Roadmap that can be found in Figure 1 on page 9. This illustration plots the expectations for technological capabilities and policy from 2020 to 2030.

It should be acknowledged that the current COVID-19 pandemic has played a significant role in societies during the development of this roadmap. Indeed, the injection of such a level of uncertainty has caused the authors of this report to reflect quite significantly. The ECOPRODIGI consortium considers this of utmost concern and thus request that users of this roadmap take the status of the pandemic into consideration when using this roadmap. As it had always been thought of as a working roadmap of the future since its beginning, prudence is required in its use and it should be suggested that users create their own updates and assessments in an ongoing fashion as the future unfolds.

Introduction - the current state of play in 2020

By 2020, global maritime governance had become more effective than ever due to the new and improving regulations and enforcement from EU, IMO, and other international bodies. Industry, responding to the demand from consumers, had stepped up with the announcement of new environmental imperatives to join the calls for de-carbonisation, zero-emission, and the electrification of the seas. Green taxes, enabled through the detailed emissions and energy consumption record keeping was affecting vessels, shipyards, ports, and other elements of the ocean economies. Sustainable practices and circular-economy thinking has received widespread attention, and demonstrated results to this end were emerging, noticeably in the Baltic Sea region where clean shipping was having a positive impact in mitigating the problems with eutrophication.

At the onset of 2020, the future vision of many industries had been a fully digitalised and optimised one. Developments in AI, machine learning and machine vision have made progress through their nascent stages of development in the decade prior. More than ever, big data collected by the ever-increasing amount and kinds of sensors and cameras had begun to be processed on remote servers. Special attention and sustained investments were ensuring that the software and algorithms that had been developed to process, manage, and visualise the data so that operators could effectively optimise workflows.

The ongoing impact of digitalisation to maritime operations has been tremendous. Data-based decision support systems have been available to the industry for some time. Now these systems are beginning to suggest optimal sailing routes; performance and monitoring systems are providing estimates for required maintenance and repairs; decisions about hull and propeller maintenance, schedule design, retrofitting, and more, are improving because they are being made on the basis of data. Ship operators are optimising vessel stowage, reducing the use of ballast water, and improving on vessel utilisation. Different kinds of fault detection and early-warning systems are being implemented to avoid accidents and breakdowns.

Digital vessel performance monitoring is beginning to offer the opportunity for ship crew to navigate ships real-time in a more energy efficient manner using robust decision support tools and models providing overview of most optimal sailing route, speed and on-board equipment used for monitoring the weather, current, wind, draft, cargo

loading conditions, and more. The advancement in software and simulation has gradually made inroads towards the realisation of the grand vision for automated ships.

The benefits of digitalisation are not confined to the ship, but rather spread across the maritime value chain. Full digital data capture and AI models are enabling truly digital and integrated logistics. Digital transparency about cargo unit positions, states, and conditions, are enabling terminals to optimise cargo operations, gain efficiencies and shorten port stays, providing ship operators with more opportunities to sail slower, reduce fuel consumption, and provide better service quality to their customers. The ports, ships and supply chain are increasingly integrated in multi-modal data platforms that enhance the efficiencies of stowage and voyage planning and execution. Ship location data are beginning to be translated into real-time arrival estimates allowing ports to act and react on better information to lower time in port and increase time sailing. This intensive use of real-time data throughout the supply chain opens up for more secure and efficient coordination and planning of all operational links in the chain, and contributes to the competitiveness of Ro-Ro shipping, especially in relation to rubber wheel traffic / lorries on land, which continue to be a major contributor to negative environmental impacts.

3D scanners and computer vision have the potential to make stowage operations more efficient. Virtual reality and augmented reality technologies are providing process perspectives never seen before. Increased data sophistication, transparency, and management help to align incentives for improving cooperative performance, and giving insight into the magnitude of the inefficiencies that are yet to be mitigated, or in other words, the money left on the table and the unnecessary destruction to the environment.

The evolution of the maritime and related industries towards digitalisation has meant that there is an increasing demand for different skillsets than before. The work that could be removed from the crew and captains has being assigned to partially autonomous systems at the benefit of increasing safety and decreasing human error. In other words, captains and crew are being challenged by new technologies, and new skills are required to be able to manage the technology effectively while also improving the work environment and occupational health. The arrival of big data requires more data analysts and improved data science architects. This, in turn, requires not only requirements for new ways of learning and training, i.e. through simulation, but effective and experienced managers and leaders are needed to see this transition through. Special attention must therefore be placed on making the image of the industry an attractive place to form a career.

In the midst of all this development, the continuance of these trends has been called into question. Not only due to the corona virus, but also e.g. cyberattacks have thwarted confidence in digitalisation: the quantity and magnitude of the attacks,

spoofing, cyber-terrorism, and ransom, are reaching a critical point. And much goes unreported. To protect all sorts of assets, encryption technology and distributed ledgers are being considered to play an increasing role here.

The environmental agenda is also at stake. Initiatives from the International Maritime Organization (IMO) - the Marine Environment Protection Committee (MEPC) have put forward a series of measures aimed at reducing the total amount of greenhouse gas (GHG) emissions from ships in line with the UNFCC's Paris Agreement and UN 2030 Agenda for Sustainable Development. By April 2018, the IMO adopted an initial strategy to reduce annual GHG emissions by 50% by 2050 compared to the 2008 level. The effectiveness of this will unfold over the next decade.

If the disruptions of 2020 are overcome, the techno-regulatory regimes continue in their progress, and investments and policy can continue their trajectory, then the decade is likely to become a decade of eco-efficiency. However, advancing industry standards are needed in that standards organisations, classification societies, and industry continue to push for the establishment of harmonised rules and communication to unlock the value promised in an increasingly digital era.

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A brief history of the maritime industry in the 21st century

Year 2000

Notwithstanding the dot com bubble burst in March of 2000, Europe was experiencing a period of healthy territorial, economic, and technological growth at the onset of the new millennium. Europe's Ministerial Intergovernmental Conference on Accession Negotiations with numerous Eastern European countries opened in January. Fuel prices had been low for some time, and industrial output was high, with China's entrance into the WTO resulting in the dramatic expansion of trade to and from Southeast Asia.

Confidence in the maritime industry was strong, and both large and small companies were succeeding. The demand for new vessels was high and the orderbooks at the shipyards were full. The low fuel prices, coupled with high demand and freight rates, meant profitable times for maritime transport.

Ships were getting bigger and faster. Prior to 2000, a large container ship could carry around 4000 TEU, and capacity would soon expand to carry 7000-8000 TEU. Roll-on Roll-off (Ro-Ro) vessels were also getting bigger and scheduling more frequent departures. To pace the increasing demand driven by global GDP growth, vessel types were diversifying. Demand for built-for-purpose vessels grew, with new mixed cargo, service, passenger and work ships filling the orderbooks in European yards. Yards were not making everything by themselves anymore, but outsourcing and sub-contracting practices spread, with the establishment of local and global supply chain networks. Shipbuilding had already evolved towards block construction that meant that not everything - hulls included - had to be both built and assembled on the spot. Ship design companies were internationalising and finding new markets globally. Yard orders were booming in years 2004 to 2008 with a large number of newly built yards being opened in Asia, and particularly in China. The delivery of main engines for propulsion of the growing fleet became the bottleneck.

Globalisation was beginning to affect the ownership of the companies across many parts of the value network - among maritime segments (i.e. container shipping and Ro-Ro), ports, and yards. The industry was moving towards a duality of huge companies and their smaller subcontractors.

With increased resources, more standards, and access to global solutions, the investment, development, and implementation of digital technologies in maritime and related industries had expanded - albeit gradually. Internet connections were more ubiquitous with the standardisation of Wi-Fi and growth of mobile telephony. Telefax was widely used in maritime, as there were computers in the offices, but typically few on-board ships. The first web portals for tendering and purchase orders in the industry were starting to open. Morse code was finally discontinued in maritime communication in 1999.

In the year 2000, health, safety and environment (HSE) procedures were mostly already developed, however the industry experienced more accidents relative to today. Tragic accidents in the late 1980s and early 1990s lead to a series of new regulations that would come into force around 2000, such as an update to the IMO's Safety of Life at Sea (SOLAS) and the International Safety Management (ISM) code. These mandated not only new behaviours, such as checklist-based reporting procedures for monitoring and reporting, but also the shift in paradigm from deterministic to probabilistic methods and the further implementation of new technologies and stricter requirements for them. After the accident of the M/S Estonia in the Baltic Sea with the loss of 852 lives, new regulations resulted in safety retrofits for Ro-Ro vessels: new validation procedures and calculations on aspects such as stability requirements, flood control doors, watertight bulkheads, bow visors, ramp functionalities, video recording requirements, alarm systems, and more, were brought about in the Stockholm convention. The impact of new regulations had not been so great, arguably, since the Titanic, in the aftermath of the regulations that followed in the wake the M/S Estonia.

As ships were required to record what they were doing in much greater detail, inspections were still conducted manually which left open the many possibilities for human error. Yet the processing power of computers was making analysis more of an automated process. The first flowmeters for monitoring fuel usage that would revolutionise vessel performance management and optimisation were being installed on vessels. Ship design companies were progressing in the migration to integrated 3D modelling software such as Computer-Aided Design (CAD). Likewise, improvements in Computational Fluid Dynamics (CFD) and materials were resulting in ships that could sail faster without increasing fuel usage. Accident reconstruction techniques improved as well that helped to further identify risks.

Consequences for human resources were also beginning to emerge. The idea of dual officers who are familiar with both navigating and engineering was surfacing. Robots were becoming more common in manufacturing processes that would foreshadow the later automation of the workforce in European shipyards and ports. With the increasing use of subcontractors, supply chain management tools had to be developed in order to organise workflow efficiently.

Sustainability was not on the maritime agenda in the year 2000. Climate change was recognised, but no efforts had been initiated to mitigate it in the shipping industry. Other environmental issues, such as eutrophication of the Baltic Sea, were seen as more urgent, and the effect of ship emissions on air pollution was recognised and efforts to limit them began. The first Sulfur Oxides (SOx) regulations had been enforced in the late 1990s, and environmental cooperation around the Baltic Sea Region countries was increasing – in particular through the Helsinki Commission (HELCOM). In Gothenburg, the first shore-power electric connections were offered in order to decrease smog and air pollution in the area. The first Sulfur Emission Control Area (SECA) was implemented in Sweden in 2005, tightened and expanded in 2010, and then again in 2015.

Maritime Industry from 2010

2010 was characterised as a post-financial crisis pre-recovery low point for shipping and shipbuilding. The financial crisis and the subsequent recession led to lower demand for consumer goods and oil. Given that the largest container ships had quadrupled in size to 16000 TEU since 2000, overcapacity was resulting in a decline in asset values. The orderbooks for large vessels at European yards were empty, and what orders there were for large cargo vessels were being taken by Asian shipyards.

An increasing environmental consciousness had resulted in international debate and a series of political and regulatory actions that affected the maritime industry. While initiatives with the aim of reducing pollution from the world's merchant fleet date back to at least 1973 when the first edition of the International Convention for the Prevention of Pollution from Ships (MARPOL) was adopted by IMO, many updates had followed. By 2010, the techniques and technologies for calculating emissions and corresponding energy efficiency had matured and were being incorporated into new ships. Further guidelines would follow, including the Annex VI regulations on Energy Efficiency Design Index (EEDI) aimed to reduce fuel consumption through technical and design-based measures, as well as the Energy Efficiency Operational Indicator (EEOI) and Ship Energy Efficiency Management Plan (SEEMP) to evaluate and improve the fuel efficiency of existing ships.

Further regulatory advancements had been in design and taking hold in the industry around 2010. Concerns over SOx emissions had grown over the previous decade, and the installation of the first sulphur scrubbers on ships began. Slow steaming was urged as another approach to decrease emissions (a strategy that coincided with overcapacity). New SOLAS regulations were adapted to pay more attention to damage stability, and cabins were no longer allowed to be constructed under watertight decks.

These complexities boosted the role of advanced techniques in shipbuilding. While many of the new orders for large ships were headed to the Far East, European yards had begun specialising in high-tech and complex vessels that were in demand given the growth in emerging sectors such as offshore wind, as well as the growing popularity of the cruise tourism industry. Shipowners were experimenting with alternative fuels as a power source, for example LNG and methanol. The technology suppliers to the shipbuilding industry were, by this time, well-established across the global shipbuilding markets.

But although environmental disasters had been reduced by the improved regulations, techniques, and safety protocols, they did not disappear. The Deepwater Horizon oil disaster in 2010 would impact the offshore industry and usher in further HSE regulations. In line with the worldwide trend for sustainability that was garnering a foothold across industries, international emissions regulations were tightening, and the concept of clean shipping became more visible, especially in fragile areas such as the Arctic and the Baltic Sea Region. To decrease the hazards and material waste from the other end of the ship's life cycle, increasingly more attention was paid to developing proper ship recycling practices.

While leaps in connectivity had, by this time, integrated on-shore economies, shipping held onto older technologies. Over the seas and oceans, broadband connectivity, AIS data, and satellite coverage was limited and unreliable. Port operations and berthing was conducted via phone and radio. First generation of ECDIS (Electronic Chart Display and Information System) had been developed and implemented on ships more and more - but not without problems related to cybersecurity. Digital monitoring was becoming more common, but the majority of ships had yet to even install flowmeters or other devices to monitor their fuel consumption.

The purpose of this introduction has been to present a current state of play and a brief history of maritime and related industries since 2000. From here, the report will begin to lay out a vision for the future. The next section will present ECOPRODIGI's roadmap that illustrates a trajectory for the industry. Following the roadmap, descriptions of the events presented in the roadmap can be referenced for more information. Following that, a set of scenarios are offered from which readers can utilise to assess the robustness of the roadmap. In the appendix, readers can find details of the methods that were used to construct the roadmap.

The future of Ro-Ro and Ro-Pax shipping:

An innovation and policy roadmap for digitalising integrating ship operations

2022

01. AIS data used to coordinate the existing fleet

2023

02. Automated mooring systems available

03. Fuel & cargo data used to audit vessel performance

04. Hull & propeller maintenance supported by AI

05. Predictive maintenance tools available for engines & systems

06. Onboard sensor & equipment calibration via live video

07. Crew & staff have real-time performance analysis

08. Stability & trim optimised on data

09. Voyage planning & execution supported by AI

2024

10. AI-enhanced cameras at terminals & onboard ships

11. Engine & subsystem maintenance supported by AI

12. Cargo ETA to terminal tracked & shared

2025

13. Terminal operations & cargo stowage system integration

14. Aerial drones support ships' navigation & berthing

15. Cargo info shared in real-time across network

16. Contracts penalise late-arriving haulage carriers

17. Cargo condition data shared across network

18. Terminal operations & stowage aided by AI

19. Vessels assessed & valued based on EEXI & MRV

20. International standards for maritime cyber security

21. Multipurpose drones stationed at ports
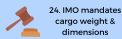
22. Voyage (noon) reports replaced by sensor and satellite data

23. Standards for sharing vessel positions across ports

24. IMO mandates cargo weight & dimensions

2026

25. International vessel voyage codes for Ro-Ro vessels
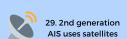
26. Shipowners taxed on their CO2 emissions

27. EU mandates cold ironing at ports for Ro-Ro vessels

28. Remote controlled terminal tugs (un-)load cargo

2027

29. 2nd generation AIS uses satellites

30. Bunker fuel taxed

31. International standards for sensor data logging & exchange

2028

32. Robots perform lashing operations

33. International cold ironing mandate implemented

Roadmap elements

01   AIS data analysis used to provide insight on- and recommendations for- the existing fleet

The Automatic Identification System (AIS) is developed "to improve the maritime safety and efficiency of navigation, safety of life at sea and the protection of the maritime environment" [1]. Requirements and plans for implementation of the AIS system is that it is to be fitted to all ships of 300 gross tonnage and upwards engaged on international voyages, cargo ships of 500 gross tonnage and upwards not engaged on international voyages, and all passenger ships irrespective of size [2].

The VHF-based system broadcasts position reports including information about the vessel and the voyage. However, the vessel information is valuable for other purposes, especially the capability for long-range tracking, which can provide important insight into the energy efficiency of the existing fleet, where information about ships' speed, routes and other operational parameters can be used for analysis [3].

References:

[1] IALA, IALA Technical Clarifications on ITU Recommendation ITU-R M.1371-1, Edition 1.4, 2003.

[2] IMO, International convention for the Safety of Life at Sea (SOLAS), Chapter V Safety of Navigation, Regulation 19, 1974/1980

[3] UCL Energy Institute, Assessment of Shipping's Efficiency Using Satellite AIS data, Prepared for the International Council on Clean Transportation Tristan Smith, Eoin O'Keeffe, Lucy Aldous and Paolo Agnolucci, March 2013

02   Automated mooring systems that perform the berthing process are commercially available

Berthing vessels is a time and energy intensive activity, with little room for error. As vessels approach the quay, tugs are often used to move vessels into position, mooring lines are fastened and the ship is carefully drawn close to the berthing side. When berthed, the challenge becomes one of keeping the ship steady in changing weather and tidal situations.

Self-tensioning mooring arrangements can reduce time needed to moor and to adjust the parameters of the moorings [1]. Even more complex systems can make mooring lines obsolete either by using high-powered electro-magnetic or hydraulic systems [2]. Such systems could extend the "reach" of the port, effectively capturing the vessel on approach, and shifting the mooring operations to portside. This would reduce the labour and energy intensity of the process and decrease the time needed for mooring and unmooring.

References:

[1]   http://www.cavotec.com/en/your-applications/ports-maritime/automated-mooring

[2]https://www.macgregor.com/Products/products/port-and-terminal-equipment/automated-onshore-mooring-system-moorex/

03   Fuel consumption and cargo data are used to audit vessel performance over time

The European Union's MRV Regulation on the monitoring, reporting and verification (MRV) of carbon dioxide emissions from maritime transport entered into force on 1 July 2015 (Regulation (EU) 2015/757, and amending Directive 2009/16/EC) [1]. The IMO recently followed in the footsteps of the EU, and implemented amendments to the MARPOL Annex VI on data collection systems for measuring the fuel oil consumption by ships by adopting MEPC.278(70) which entered into force on 1 March 2018 [2].

Under the amendments, ships of 5.000 gross tonnage and above are required to collect consumption data for each type of fuel oil they use, as well as other, additional, specified data including proxies for transport work. The aggregated data is reported to the flag states after the end of each calendar year and the flag states, having determined that the data has been reported in accordance with the requirements, issue a Statement of Compliance for the ship.

Flag states are required to subsequently transfer this data to an IMO Ship Fuel Oil Consumption Database. The IMO will be required to produce an annual report to the MEPC, summarising the data collected. In addition, ships of 5.000 gross tonnage and above shall as part of the Ship Energy Efficiency Management Plan (SEEMP) include a description of the methodology used to collect the data and the processes used to report the data to the ship's flag state.

A comparison of the EU MRV and IMO DCS systems is visible in table below [3]:

	EU MRV	IMO DCS
Entry into force	1st of July 2015	1st of March 2018
Scope	Ships above 5'000 GT Voyages to / from EEA ports of call	Ships 5'000 GT or above International voyages
First monitoring period	2018	2019
Procedures	Monitoring plan (37 sections)	Data Collection Plan (SEEMP Part II) (9 sections)
Compliance (procedures)	Assessment report (no need to be on-board)	Confirmation of compliance (must be on-board)
Reporting	Fuel consumption (port / sea) Carbon emissions Transport work (actual cargo carried) Distance sailed Time at sea excluding anchorage	Total fuel consumption Distance travelled Hours underway Design deadweight used as a proxy
Verification	Independent accredited verifiers	Flag administrations or authorized organizations
Compliance (reporting)	Document of Compliance (June 2019)	Statement of Compliance (May 2020)
Publication	Distinctive public database	Anonymous public database

References:

[1] https://mrv.emsa.europa.eu/#public/eumrv

[2] http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Data-Collection-System.aspx

[3] https://www.dnvgl.com/maritime/insights/topics/EU-MRV-and-IMO-DCS/index.html

04 Hull and propeller maintenance strategies and scheduling are supported by AI

Identifying the root causes of the sources of eco-inefficiencies is not straightforward. Solution making has become an activity of costly trial-and-error, requiring experts in performance management to develop multiple hypotheses and action plans. Data-based decision support can significantly improve the quality of decisions in such situations.

Installing sensors on board to send and receive real-time data will make it possible to develop AI models for prediction to reduce uncertainties and scatter significantly related to the effects of dry-docking, paint system performance, hull cleaning, and propeller efficiency. Advanced modelling can enable the crew and technical managers to implement condition-based and predictive maintenance algorithms, leading to better hull and propeller strategies, saved fuel costs, and

reduced emissions to the environment, and thereby improving overall ship performance, and reducing maintenance and repair costs.

05 Predictive maintenance tools for engines and sub-systems are commercially available

Ships need ongoing management and maintenance to keep them operating efficiently. Currently, ship operators do not have access to models which can predict deterioration of performance or equipment part failures. Installing more sensors on engine equipment makes it possible to develop AI models for prediction of engine performance problems and fault detection based on high-frequency, real-time data. This can support crew on-board and operators with condition-based and predictive maintenance, thereby improving engine and equipment uptime and reducing maintenance and repair costs.

Equipment manufacturers will be integral for not only the installation of sensors and logging of high frequency data, but in the construction of the models. However, manufacturers only have limited access to on-board equipment - usually with regards to the condition of the equipment. Giving the manufacturers access to data, maintenance schedules, breakdown history, etc. will supply them with data for modelling advanced decision support systems that will improve prediction, reliability and performance of their equipment, while minimising the costs of ensuring uptime of equipment through better maintenance.

06 Sensor and equipment calibration is performed by the crew, assisted by experts via online video conferencing

Sensors and equipment on-board a vessel need maintenance in order to function properly and record accurate data. Over time, these data-gathering devices drift, and require calibration and upgrading to be able to perform the task as intended.

Current practice sees specialised representatives from the manufacturers boarding ships while at berth in order to maintain the sensors. However, with improved connectivity, crew could be guided by these experts to perform the tasks on board. This would decrease the costs for the manufacturers of having to send specialists around the world. This would follow the trend towards virtual surveys and inspections undertaken by classification societies for renewing statutory certificates [1].

References:

[1]https://www.offshore-energy.biz/shipping-industry-sees-growth-in-remote-surveys-in-times-of-coronavirus-crisis/

07   Real-time performance data analysis is available to land-based staff and crew on-board

The objective of a vessel performance management system is to optimise the efficient operation of a vessel. This is dependent on reliable data. Currently, measurements of performance include fuel consumption, ship speed, sailing direction, as well as the external parameters such as wave height, wind speeds and current direction and force. These are prepared by the crew and transmitted to shore-based analysts via daily voyage (noon) reports. These analysts normalise, visualise, and compare the performance with a baseline performance model of the vessel.

A big challenge given this method is the scatter in the normalised data, which has a large influence on the results and thereby the final recommendations. Better data, delivered by auto-logging, combined with AIS and hindcast data, is possible. This would allow for more precise modelling and improve the decision support for voyage optimisation.

However, the crew on board is not aware of the importance of quality data measurements because they are not involved in the analysis. Because they are not involved in the analysis, they are not involved in the resulting decision-making. The crews of most vessels are likely to be motivated to improve the performance of the vessels if they become more involved in the optimisation process, for example in the development of best practices for voyage execution as well as speed and engine settings.

08   Vessel stability and trim are optimised based on data rather than estimates

To maximise fuel efficiency, cargo ships would need to operate at minimal trim and heel and take on a minimum amount of ballast water. However, inaccurate measurements of the cargo weight and their placement on-board put the entire ship at risk for capsizing.

Current practice sees the terminal distributing a cargo manifest based on information received from the cargo owners. Unfortunately, the weight provided in the manifest is not in all circumstances exactly known – but given as an estimate. Estimates are also produced for the position of the cargo on deck, as the final position of the unit is not required to be registered. This gives rise to inaccuracy in both the determination of position of the center of gravity (the stability) and the optimal trim of the vessel.

Ideally, the cargo units would be measured for their dimensions and weight when entering the port, and models would be used to suggest operational parameters [1]. Further cargo unit data, such as type classification (dry / reefer, dangerous cargo, etc.), are also necessary for planning the positioning of the cargo. The master must ascertain and record that the ship is in compliance with all stability regulations, and only then may she determine the ship's trim and stability.

References:

[1] https://www.econstor.eu/bitstream/10419/179203/1/adbi-wp747.pdf

09   Voyage planning and execution is supported by AI

The amount of data available from the vessel is increasing, making it possible to create AI models that incorporate machine learning, neural networks and/or data analytics to enable intelligent decision-making.

Combining noon data report data from longer periods using AIS and hindcast data, more precise data modelling would enable the shipping companies to evaluate the effect of different voyage execution decisions taken under various weather conditions. The AI systems could be enabled to make adjustments to the voyage, and learn from these adjustments.

10   Cameras with AI-enhanced object recognition support cargo operations at terminals and onboard ships

Machine vision technologies can be applied for both static object recognition, identification, and detection, as well as dynamic motion analysis to track speeds and flow [1]. Vision systems in the form of visible light cameras are today an integrated part of Optical Character Recognition (OCR) portals at many Ro-Ro / Ro-Pax terminals [2]. They support automated gate-in / out of vehicles and lorries / trailers entering / leaving the terminal area and enable identification of license

plate numbers as well as shooting a series of panoramic images to capture vehicle / cargo unit conditions and for safety purposes [3]. It is however possible to imagine a wider extent of application areas for vision / camera technologies to support terminal and cargo operations.

Most computer vision systems use visible-light cameras passively viewing a scene at frame rates of at most 60 frames per second, but can also use image-acquisition hardware with active illumination such as structured-light 3D scanners, thermographic cameras, hyperspectral imagers, radar imaging, LIDAR scanners, magnetic resonance images, side-scan sonar, synthetic aperture sonar, and more. Camera or hardware captured "images" are subsequently processed often using a set of computer vision (AI) algorithms to enable automatic process control and decision support.

Vision systems and AI algorithms can potentially be used to validate vehicle and cargo unit dimensions and weight at gate in from images taken, and in the future, track and monitor vehicle and cargo unit positions and conditions. They could also enable on-board capture of vehicle and cargo unit positions and passenger movements, improving the degree of automation of different work processes including stowage, loading, and discharge processes.

References:

[1] https://en.wikipedia.org/wiki/Computer_vision

[2] http://harboursreview.com/tallink-and-taltech-team-up-to-develop-smart-car-deck-solutions.html

[3] https://www.youtube.com/watch?v=_l658L-Zyfk

11   Engine and subsystem maintenance scheduling is supported by AI

The amount of data coming from the engine and its subsystems are increasing, yet many ship operators struggle with engine and subsystem underperformance, as it is not easy or straightforward to identify the root causes of this.

Data from the engine and sub-system, when compared across the fleet, will firstly enable predictive maintenance scheduling. Beyond this, AI will be able to not only optimise performance, but be able to make adjustments to the system, and then learn from those adjustments that it makes to regulate itself.

The data required for this must be generated, formatted, and then made available and automated for the AI system. It will also need to be trained on maintenance scheduling and performance history. The promise of AI is that of a smarter way of

optimisation discovery, that, when rolled out to the fleet, can bring significant gains of eco-efficiency for the industry.

12   Cargo location information is shared to provide the ETA to terminals

Waiting for cargo to arrive at the terminal, and the uncertainty about when it will eventually arrive, is a real pain-point for maritime logistics and stowage planning. Communicating the estimated time to arrival of cargo requires significant attention, resources, and planning systems that are adaptable as information on cargo arrivals is constantly updating. Because there are many actors that are responsible for transmitting this data, the information flow is erratic, and so executing stowage plans is always ad-hoc and sub-optimal.

Location data on cargo and lorries, with updating estimates for the time of arrival, could provide information on the reality of the estimated time to terminal. Installing trackers and sharing positioning data could be fed into a system that would provide stowage planners with an overview of the arrival at terminal estimations that could improve the decisions on loading and planning.

Such location tracking capabilities are available on mobile phones, and determining routes and traffic conditions *en route* could notify stowage planners of delays as they develop. Delayed cargo can be notified of the need for rebooking when cut-off limits are anticipated as unreachable, reducing the need for unsafe behaviours such as speeding. Furthermore, this could be used to document arrival times in order to incentivise and reward on-time arrival.

13   A system for integrating terminal operations and cargo stowage is commercially available

Ro-Ro and Ro-Pax vessels travel on short sea routes, and at each port of destination, cargo is unloaded and loaded. Stowage planners must determine a suitable configuration so that segregation rules and safety requirements are satisfied, taking into account for loading and unloading at intermediate destinations, and accomplish this in a sequence that attempts to minimise time at port and tug driving expenses. This comprises the cargo stowage problem.

Artificial Intelligence (AI), machines or computers behaving in ways that previously were believed to require human intelligence, could be reasonably applied to match, optimise, and eventually transform the cargo planning process. Developing a stowage plan currently relies on the skills and decisions of human

planners, using several planning documents and tools in order to accomplish and log this, including locally-developed applications, such as Excel with CAD Drawings, or in a TOS (Terminal Operations System) that draft high-level stowage plans for the different decks of the ships that are customised for the particular routes and vessels in Ro-Ro shipping.

AI could observe and learn the "normal behaviour" of the stowage process, find better solutions and anomalies, and accelerate the decision-making processes and workflows. However, an integration of the software and data needed to execute the stowage plan would be necessary to allow for AI-based planning support. Accomplishing such integration could further allow for earlier estimates of the time to availability of the cargo at the destination port that would decrease waiting times and improve efficiencies of other cargo handlers in the network.

14   Aerial drones, stationed on vessels, support navigation and berthing

Technological advances see drones becoming lighter, capable of travelling greater distances, equipped with diverse sensor technologies, carrying heavier loads, and operating autonomously. As drone technology becomes cheaper and more affordable, the commercial drone market is expected to grow tenfold from $4bn in 2018 to $40bn by 2023 [1, 2].

Many Ro-Ro vessels face navigational challenges during berthing or mooring operations, such as turning in tight spaces and, depending on the weather conditions, limited visibility. Consequently, 54% of all ship accidents in 2018 were due to navigational issues such as collisions with ships, icebergs, marine infrastructure or contact with the seabed/grounding [3]. Current practice sees ships use a combination of radar and manual human assistance to avoid collisions.

Multi-purpose drones, using cameras and advanced sensors, would be able to detect close obstacles such as icebergs or small boats and determine the distance between maritime infrastructure and ship to provide the captain accurate and real-time data. Moreover, drones can take photos in case of damage to the ship and could taxi small goods from one ship to another across distances.

References:

[1] https://www.businessinsider.com/drone-technology-uses-applications?r=US&IR=T
[2] https://www.ft.com/content/cbd0d81a-0d40-11ea-bb52-34c8d9dc6d84
[3] http://www.emsa.europa.eu/publications/technical-reports-studies-and-plans/item/3734-annual-overview-of-marine-casualties-and-incidents-2019.html

15   Cargo information is shared in real-time across the maritime supply chain

Optimising cargo planning and stowage is entering a new phase with the implementation of new maritime communication systems. Real-time connectivity and integration with ports and cargo owners, handlers and operators is opening for the possibilities of seamless cargo movements.

Sharing information as soon as it becomes available can update the status of planning and coordination activities, and adjustments can be made to optimise based on contingencies. However, there are still many places in the world with poor and unreliable connectivity. If the ships' planning systems shall be updated along the route, a satellite-based connection is likely requirement, meaning that investments in equipment, platforms, display systems, and interfaces are necessary.

16   Commercial contracts incentivise haulage companies and carriers to arrive on time or face penalties

Cargo that is delayed en route to the terminal is a major source in inefficiency in the transportation network. Smart contracts between carriers and cargo handlers can incentivise those delivering cargo to the terminal to arrive on time and in the correct state or face penalties [1,2].

With the introduction of location-enabled IoT devices and blockchain, this process could be made transparent using a single database running an embedded self-executing smart contract system. Such a system would reduce uncertainty on the liability of cargo claims, remove the need for intermediary, and speed up reconciliation between transacting parties. It could furthermore reduce the need for paper-based documentation and the associated costs of their safekeeping.

References:

[1]. Christidis, K. and Devetsikiotis, M. (2016). Blockchains and Smart Contracts for the Internet of Things. IEEE Access, 4, pp.2292-2303.

[2].https://medium.com/harvard-business-school-digital-initiative/maersk-reinventing-the-shipping-industry-using-iot-and-blockchain-f84f74fe84f9

17 Cargo condition data is shared across the supply and service network

There are many actors involved in transporting cargo: Owners, road transport companies, warehouses, ports and terminals, ship operators, authorities, insurance companies, and more. When cargo is damaged, it can be difficult to trace responsibility and assign liability.

Despite the fact that platforms for tracking and tracing like GPS and GPRS have been available for more than a decade, there is a lack of uniform standards for sharing data. Sharing data would require that different actors migrate away from the proprietary technologies and platforms they have developed - often independently from other stakeholders - and invest and operate a "shared" system. Furthermore, there are coverage limitations for GSM/3G in certain locations, making holistic uptake problematic.

Advancements elsewhere have been made: The car industry uses "Odette," the paper industry uses "papiNet," but even within these systems, actors are not always willing to share data given the presence of competitors. Solutions are being worked through in these shared networks, where the owner of the cargo can decide who needs to have access to what information. [1] In container shipping, the Digital Container Shipping Association (DCSA) recently published a common set of processes as well as data and interface standards for Track and Trace (T&T) that can be implemented by carriers, shippers and third parties to enable cross-carrier shipment tracking. [2, 3]

References:

[1] https://www.unece.org/cefact.html

[2] http://dcsa.org/initiatives/data-and-interfaces

[3] https://app.swaggerhub.com/apis/dcsaorg/DCSA_OAS/1.0.0

18 Decisions on terminal operations and vessel stowage is aided by optimisations/artificial intelligence (AI)

Current planning of load and discharge operations for Ro-Ro vessels is done using cargo lists and deck position data from a terminal operating system (TOS). This information is then combined with the experience and simple application rules of the planner or tug dispatcher for decisions on sequencing load and discharge.

AI models can provide suggestions for how to load and discharge vessels, per and across decks with the purpose of minimising tug driving expenses, minimising the port stay in order to enable slow steaming on the sea leg, and reduce tug and ship emissions. AI systems would learn from past events to forecast bookings, likelihood of no-shows, and possibilities for complicated dual cycling (simultaneous load/discharge) manoeuvres. These would be tailor-made for vessels, terminals, and routes.

AI models should be able to predict within a more precise confidence interval when cargo will be available at the yard for pick up. This enables terminals and haulage companies to time the pick-up better, optimise workforce, and thereby improve utilisation of the cargo terminal area, and furthermore reduce lorry idle and waiting times.

19 Existing vessels are valued based on data derived from their past operational performance (EEXI and MRV)

The selling and purchasing of second-hand vessels are complex transactions. Vessels are large assets that are valued across many parameters. While valuation is dependent on the market that they are applicable for and the current cargo rates that are being charged, they are also rated on their eco-efficiency performance - the holistic costs for their operation.

Performance-based valuation is difficult to assess across vessels because all vessels are different and there is a lack of standard measures for their assessment. The International Maritime Organization (IMO) has proposed an Energy Efficiency Existing Ship Index (EEXI) to rectify this by standardising energy efficiency performance measures. In turn, this would improve transparency across the market for second-hand ships in terms of effects on the climate and promises to make investments in second-hand vessels less risky [1].

In the end, improving information about vessels offers an opportunity to reduce uncertainty and increase the market volume for the purchase and sale of second-hand vessels.

References:

[1]http://www.imo.org/en/MediaCentre/PressBriefings/Pages/26-ISWG-GHG.aspx

20 International standards and protocols are implemented for maritime cyber security

As the digital revolution transforms maritime, cyberattacks are keeping pace. If the industry aspires to increase in digital integration, automation, and e-navigation, the vulnerabilities of interconnected systems will materialise, and not only at the weakest points of protection.

Cybersecurity is high on the agenda given the high frequency and the magnitude of attacks [1]. Cyber-specific amendments to the ISPS and ISM Codes will enter into force 1 January 2021. The current opinion in the industry is that the costs of implementing cyber security standards and protocols outweigh the benefits of being protected. This perception is problematic considering that very few cyber security breaches are reported, and so a first critical step towards a solution is to document and share knowledge on incidents so that the entire ecosystem can be made aware of the risks and to take appropriate measures towards immunity.

Furthermore, standards will need to address the increasing digitalisation and electronic system integration of a wide range of operations e.g. the record keeping on transactions, human resources, loading and discharging cargo, container location and particulars, and sharing of this data across transport modes and partner networks. This requires extensive cybersecurity standards and protocols.

References:

[1] http://www.futuredirections.org.au/publication/the-global-maritime-industry-remains-unprepared-for-future-cybersecurity-challenges/

21 Multi-purpose drones, stationed at ports, are providing simple services

Ports are specialised and critical infrastructure where many different activities are undertaken. They are large industrial spaces where the land meets the sea and where goods are transferred across rail, road, and maritime. Transactions and exchanges at ports require services of various kinds to ensure timeliness, safety, and legality.

As ports explore ways to keep up with increasingly complex activities and volumes, drones can be used to perform various tasks [1,2]. For example, in the offshore industries, drones are being used to inspect infrastructure and assets, and have

reduced inspection times from 8 weeks to 5 days [1]. Drones stationed at ports can similarly complete tasks, such as inspecting cranes, inventory control and locating misplaced goods, and the surveillance and detection of break-ins. Drones could survey harbours to provide the ports and approaching vessels with a higher perspective to assist in vessel berthing and manoeuvring by surveying the harbour. They could be used to deliver and retrieve documents, tools, and parts not only around the port but also to vessels passing by.

As drones are increasingly programmed to fly autonomously, less reliance will be made on trained pilots, and machine-learned drones will navigate to beacons and react based on data it collects from surroundings [2].

References:

[1] https://www.rolandberger.com/en/Publications/Drones-The-future-of-asset-inspection.html

[2] https://www.theexplorer.no/solutions/stabilised-drone-platforms-for-offshore-renewable-energy-production

22   Voyage (noon) reports are replaced by sensor and satellite data

Chief engineers are responsible to prepare the voyage reports for submission to the company and shore management. Much of the data is derived from onboard sensors and gauges, such as remaining fuel on board and propeller revolutions. Other measurements and readings are taken external to the ship in preparation: wind speed and directions, general sea and swell conditions, and GPS provided location. Estimations must be also made: Average engine RPM, average speed, estimated time of arrival to the next port, engine distance, and other relevant standardised data.

Although Internet access is increasingly available, and data exchange is improving across the seas and oceans, persistent limitations have drawn ships closer to shore to try to access land-based Wi-Fi, sometimes resulting in disastrous causalities [1]. Furthermore, incentives exist for misrepresenting the data if ships are to meet their performance targets. Replacing voyage (noon) reporting with sensor and satellite data could help overcome these challenges, and lead to better, whole-day models for informing technical conclusions, operations, and decision-making on voyage execution.

References:

[1] Birthday party and quest for wifi revealed in lead up to Wakashio grounding off Mauritius. Retrieved 01-10-2020.

23 Standards are approved for sharing on vessel positions across port

Bottlenecks at ports are a major source of delays, inefficiencies, and costs for the shipping industry. However, it is believed that this problem can be reduced through improved coordination. Integrating VTS (Vessel Traffic Service) across the port network with international (IMO) standards for data and data sharing will ensure that all stakeholders are aligned and informed about vessel positions and plans.

Port VTS responsible for communication between port and ship, has long established protocols for communication between VTS and ships [2]. However, the regulation is about radio communication, and does not cover the communication across ports. Today, most ports are provided with information about ship and traffic by use of radars and radio communication. Using advanced e-navigation systems and digital data from the ship (e.g. AIS data), coupled with IMO standards for data sharing on vessel positions across ports, timelier and more accurate information would be available for coordinating traffic to reduce waiting and turn-around times, and delays due to congestion.

References:

[1] IALA Vessel Traffic Services Manual Edition 6

[2] IMO STANDARD MARINE COMMUNICATION PHRASES (SMCP), NAV 46/INF.4, IMO 2000

24 IMO mandates that cargo measurements (e.g. weight and dimensions) are taken

In 2016, the International Maritime Organization (IMO) implemented a SOLAS amendment requiring that containers and their contents must be weighed prior to loading. This increased the safety of container vessels, improved vessel stability, and reduced the risk of collapsing container stacks [1].

For Ro-Ro shipping, equivalent regulation is not in place currently, partly due to the fact that cargo units and trailers are not stacked on top of each other.

However, when the IMO mandates that measurements of cargo (e.g. weight and dimensions) are taken, Ro-Ro ship operators would be able to make more accurate calculations to improve operational efficiencies, vessel stability, as well as hull and deck strength calculations using stowage software and loading computers.

References:

[1]http://www.imo.org/en/OurWork/Safety/Cargoes/Containers/Pages/Verification-of-the-gross-mass.aspx

25 International standards and protocols assign vessel voyage codes for Ro-Ro vessels

A more organised and institutionalised standards effort would clear the path for innovation and the sharing of data across the value network in Ro-Ro and Ro-Pax shipping. Inspiration for a model could come from the aviation industry. The International Air Transport Association (IATA) is a trade association of the world's airlines founded in 1945, and has worked for global standards on issues regarding safety, security, efficiency and sustainability [1]. IATA regulation and standards cover aspects such as schedule information, airport, ground, and cargo operations, ticketing, revenue management and finance, business intelligence and statistics, environmental issues, and emission calculations.

Although advancements have been made in container shipping, Ro-Ro and Ro-Pax shipping lags behind [2]. The association Interferry ensures that fair and equitable regulations exist for the ferry industry and engages in development of regulation and standards for safety and security of passengers, crew, cargo, and ships [3]. However, this shipping segment does not per say have an association taking the lead in developing and setting regional and global IT and sustainability standards for Ro-Ro / Ro-Pax ships which could be of benefit to ship owners, operators, vendors, clients, and authorities.

References:

[1] https://www.iata.org/en/publications/standards-manuals/

[2] https://dcsa.org/

[3] https://interferry.com/

26   Shipowners are taxed on their CO2 emissions

Maritime transport emits around 940 million tonnes of CO_2 per annum, making it responsible for 2.5% of all global greenhouse gas emissions. In the business-as-usual scenario, CO_2 emissions are forecasted to increase by up to 250% by 2050.

Market-based measures to incentivise the reduction of emission generated from shipping were established in the EU Emission trading system (EU ETS) in 2003. However, shipping was made exempt in 2017 in order to let the IMO try to implement a global market-based carbon reduction strategy which would have mandated global participation [2].

The IMO has formulated it´s GHG strategy. However, should its implementation become slow, the EU may consider reinstating shipping into the EU ETS by 2023.

References:

[1] Commission, E., 2018. Reducing Emissions from the Shipping Sector - Climate Action - European Commission. [online] Climate Action - European Commission. Available at: https://ec.europa.eu/clima/policies/transport/shipping_en

[2] The Maritime Executive. 2020. E.U. Emissions Trading System Excludes Shipping, For Now. [online] Available at: https://www.maritime-executive.com/article/eu-emissions-trading-system-excludes-shipping-for-now

27   EU mandates cold ironing at ports for Ro-Ro vessels

Cold ironing, the provision of onshore electricity to power ships while at berth, has been available in some ports since the 1990s. Onshore power allows ships to turn off their auxiliary engines, resulting in a significant reduction in CO_2, NOx, SOx, particulate matter, noise, and unsightly plume and smog. As many European ports have large cities developed around them, reducing pollution from the cruise, container, and Ro-Ro segments would result in healthier air and environments for the many people living there [1,2,3].

Despite their obvious environmental and image-enhancing benefits, cold ironing investments at ports around the globe are limited for many reasons, including the lack of standards for voltage and frequency, the stress of high but intermittent demands on shore-based grids, and transparency in electricity prices [4,5]. Power conversion continues to be a major complication, where vessels are often running on 60hz grids, while the European power grids are running on 50hz [6,7].

In 2019 the ISO and IEC completed the work on an international standard for cold ironing systems, asking all new ports and ships being constructed worldwide to

comply with the technical specifications of the IEC/ISO/ IEEE 80005-1 standards. The European Union Directive 2014/94/EU Clean Power for Transport on the deployment of Alternative Fuel Infrastructures obligates Member States to implement alternative infrastructure networks such as shore-side power technology by December 2025.

References:

[1] https://www.ship-technology.com/news/siemens-cold-ironing-port-of-hamburg/

[2] https://www.ship-technology.com/news/port-of-dunkirk-cold-ironing-facilities/

[3] https://www.ship-technology.com/news/port-of-kiel-shore-based-plant/

[4] https://safety4sea.com/cm-cold-ironing-the-role-of-ports-in-reducing-shipping-emissions/

[5] https://www.bimco.org/news/environment-protection/20190228-bimco-says-caution-needed-on-cold-ironing?pn=1

[6] https://www.ship-technology.com/features/feature-shore-power-green-answer-costly-berthing-emissions/

[7] https://www.seatrade-maritime.com/asia/china-mandating-shore-side-power-new-vessels-domestic-trades

28 Unmanned tractor terminal tugs are remotely controlled to load and unload cargo

Tugs are terminal tractors that are used to move containers and trailers between the staging lot and Ro-Ro vessels. These have a turning radius much smaller than semi-trucks, enabling them to manoeuvre in tight spaces on deck and in the lot. Tugs are currently operated by drivers who manually connect and disconnect the mechanical and electronic systems between the tugs and the trailer.

The automated container terminal market is expected to increase by 20% from $9.09 billion to $10.89 billion by 2023 [2]. Unmanned tugs could operate without major changes to the infrastructure of a terminal and allows ports to introduce automation gradually and flexibly, in parallel with manual operation. In some markets, personnel costs are a significant factor in container terminal economics, and it is sometimes difficult to recruit terminal tractor drivers [1]. Further benefits of unmanned tug operations could include more efficient loading and unloading, lower personnel costs, improved safety, and reduced CO_2 emissions.

Automated tugs would require not only e-navigation, but also that connection and disconnection between the trailers and the tugs are performed automatically. Accompanying this transition will be the need for systems enabling remote oversight over tug operations.

References:

[1] https://www.terbergspecialvehicles.com/en/products/tractors/yard-tractors/autotug/

[2] https://www.icontainers.com/us/2018/10/09/the-future-of-automation-at-terminals-and-ports/

[3] https://www.terbergspecialvehicles.com/en/products/tractors/yard-tractors/autotug/

29   VDES 2nd generation AIS using satellites, replaces the current AIS

The Automatic Identification Systems (AIS) is developed as a maritime safety and traffic system, operates in the maritime VHF band, reports information about the vessel and the voyage, and communicates this to other vessels in the vicinity. On-board most vessels, information is displayed on navigation screens as for example on the ECDIS. Unfortunately, data transfer across these systems is limited by receivers that need to be within the vicinity of each other. Given the increasing demand for AIS, the channels have already become overloaded and need expansion.

A proposal is to split up duplex channels that today are used for phone calls and allocate channels for data exchange systems (VDES). Implementing VDES will increase the data volume that is needed to support more e-navigation services such as search and rescue, maritime safety information, ship reporting, vessel traffic service, charts, publications, and route exchange data.

The VDES system will allow the transfer of data not only by terrestrial very high frequency (VHF) radio communication but also by satellites. Low Earth Orbiting (LEO) satellites could allow data transfer over even wider areas. However, such systems require installation of new technology both on-board vessels and on shore.

30 Bunker fuel is taxed

Bunker fuel is a low-grade fossil fuel that emits large amounts of pollution into the air and oceans. It is currently exempt from taxes.

For decades, the lack of taxes on bunker fuel has led to forgone opportunities to incentivise ship operators and owners to invest in clean sources of energy, technologies to reduce emissions, or at least to incentivise them to reduce fuel consumption [1]. Revenues from bunker fuel taxes could be earmarked to subsidise the development and uptake of energy saving technologies. This would work towards an improved climate for coming generations and less illness and premature deaths due to air pollution.

The legal basis and enforcement would be a directive that all bunker fuel is taxed. There are no prohibitions/restrictions at the IMO level on member states or groups of states from levying fuel taxes, so there would be no requirement to refer the issue to the IMO if the EU decides to go ahead faster [1]. However, the proposal that was drafted by the EU in 2011 has not been agreed upon, the main challenge seems to be the desire for an agreement that covers the global fleet.

Reference:

[1]https://ec.europa.eu/clima/sites/clima/files/docs/0036/taxation_en.pdf

31 International standards are set for the logging and exchange of digital sensor data

International standards overcome technical barriers to international commerce caused by incompatibilities among established technical solutions developed independently and separately by companies. Digital standards set definitions, syntax, methods and requirements for: The logging and exchange of digital (sensor) data from equipment and machinery onboard ships (bridge, engine room, systems etc.); data storage in on-board servers, onshore data centres, in the cloud and in data warehouses; data analysis and models; connectivity and communication standards for data transmission, sharing, and for exchanging data in digital market places (i.e. via APIs).

While general principles have been outlined for the measurement of changes and performance indicators in hull and propeller performance, their adoption across the maritime industry is slow despite obvious advantages for the industry as a whole as well as for individual ship owners, operators, vendors etc. in making use of the standards.

Examples of such standards include:

- ISO 19447: Shipboard data server to share field data at sea [1]

- IS0 19448: Standard data for machinery and equipment part of ship [2]

- ISO 19030: Standard for measuring hull & propeller performance [3.4]

References:

[1] https://www.iso.org/obp/ui/#iso:std:iso:19847:ed-1:v1:en

[2] https://www.iso.org/obp/ui/#iso:std:iso:19848:ed-1:v1:en

[3] https://www.iso.org/standard/63774.html

[4] https://www.iso.org/standard/63775.html

32 Robots perform lashing operations on Ro-Ro vessels

Properly securing the cargo on board a Ro-Ro vessel is one of the most important jobs to be done before departure. Cargo is subject to the movement of the ship: Rolling, pitching, yawning, swaying, surging, and heaving, can seriously compromise safety to the crew, passengers, cargo, and can even result in the capsizing of the entire vessel if lashing is not done properly.

Securing cargo on board a Ro-Ro vessel is accomplished with rope and/or chain lashings, combined with manual trestles. The work is done by specialists, under heavy time-pressure and in all weather conditions, and amounts to one of the most dangerous jobs in maritime [1].

Lashing robots will improve operations through higher safety and faster cargo handling [2]. Failure due to human error could decrease, and the safety, reliability, and predictability of performance could increase. Early advancement Include hydraulic trestle systems that have reduced the required amount of manpower during cargo securing operations [3]. However, ongoing challenges include the standardisation of protocols and materials' breaking load considerations [4].

References:

[1]https://www.turleylawfirm.com/library/longshore-lashing-accidents-lashing-injuries-and-lashing-mishaps.cfm

[2]https://www.mckinsey.com/industries/travel-transport-and-logistics/our-insights/the-future-of-automated-ports

[3] http://www.novatech.dk/products,trestle,71.html

[4] Todorov, M. (2016). Ro-Ro handbook - a practical guide to roll-on roll-off cargo ships. 1st ed. Cornell Maritime Press, pp.29-31.

33   International cold ironing mandate implemented

While EU regulations have slowly stimulated an uptake of cold ironing in European ports, the IMO is needed to expand onshore power standards around the globe. China has passed a regulation making mandatory requirement for new build vessels trading domestically to be equipped for cold ironing [1]. Singapore gives rebates for port services if the vessel agrees to connect to the port shore power. However, uncertainty around regulations, tax-exemptions, and rebates can be a showstopper for the roll-out of cold-ironing investments.

Despite their environmental and image-enhancing benefits for the industry, cold ironing at ports worldwide lacked for years the necessary standards for voltage and frequency [2,3]. Standards reassure shipowners to invest in standard technologies for ships: As infrastructure development advances, shipowners would be increasingly able to connect to the shore power at more ports.

The total capital cost for on-shore power supply system implementation is estimated at €7.4m for small to medium sized ports. Best-case scenarios identified the substantial external cost benefits would return the system capital and operating costs in 7 years [4].

References:

[1] https://www.seatrade-maritime.com/asia/china-mandating-shore-side-power-new-vessels-domestic-trades

[2] https://safety4sea.com/cm-cold-ironing-the-role-of-ports-in-reducing-shipping-emissions/

[3] https://www.bimco.org/news/environment-protection/20190228-bimco-says-caution-needed-on-cold-ironing?pn=1

[4] Innes, A. and Monios, J. (2018). Identifying the unique challenges of installing cold ironing at small and medium ports – The case of aberdeen. Transportation Research Part D: Transport and Environment, 62, pp.298-313.

Stress-tests for the roadmap – towards a user guide

The purpose of this section is to provide users with a means for undertaking a robustness check of the roadmap. Since roadmaps are developed from the extrapolation of available information in the present, expectations for the future often follow a logical extension of the present. As readers are certainly aware of, surprises are common as the future unfolds, and so developing a range of plausible scenarios of alternative depictions of future operating contexts can serve as backdrops against which the roadmap can be assessed for robustness.

Eight scenarios are presented below, each about a paragraph in length. Reading and reflecting on these scenarios, users can assess how each scenario might impact the roadmap or parts of it. The eight scenarios are: **1) Autonomous autonomy; 2) Circle back; 3) King quality; 4) Fast & cheap; 5) A new logic; 6) Ecosystems rule; 7) A failure of consumer-led enforcement; 8) We didn't start the fire.**

After each scenario, users will also find an assessment of the scenario. The assessments below were done by participants in a workshop: Participants were introduced to once scenario at a time, and asked to 1) Elaborate on the consequences of the scenario, and 2) Identify how it would impact the roadmap and which parts in particular might be impacted. These can be used as an additional guide for advancing the robustness check of the roadmap for the different scenarios. Users can adopt this method for their colleagues to have a strategic conversation about the future of their organisation, Ro-Ro shipping, the roadmap. Users can, together with their colleagues, compare the assessments below against the assessments of their own.

The project scope is concerned with eco-efficiency of Ro-Ro shipping in the Baltic Sea Region. Direct quotes from the participants' responses are indicated by quotation marks.

Scenario 1: Autonomous autonomy

The economic recession took its toll—especially on less efficient operators. All investment went into autonomous systems to cut costs. Autonomous machines buzz around the ports, loading autonomous lorries. Customers track the movements of their Amazon orders in real-time.

Participants' assessment

For real-time, "on the map" tracking to happen, participants explain that "data has to be recalculated at all times." The current bottleneck to the unfolding of this scenario is due to the limitations for the amount of data that can be transmitted, the "lack of communication capacity" and the "lack of frequencies" that would require the system to have undergone an "override." "Smarter systems" that allow for "data saving solutions" such as "not resending already sent data," but "only updates" were proposed as an initial step.

For the full effect of this scenario to happen, respondents point to necessary investments. Data transmission infrastructure would need upgrading to "full coverage." But even before this, "the issue of regulations, for example for Maritime Autonomous Surface Ships (MASS) should be addressed," and respondents propose that "standards should be [agreed upon] and moved forward in time." If this direction is taken, participants expect "a big change in education systems" to provide the "knowledge development" for the "skills" that would be "highly demanded."

Beyond this scenario, respondents explain how "technology implementation" and "interconnectivity" will allow "operational and commercial processes and get digitalised end2end." This development will further "enable authorities to monitor and track all cargo [...] vessel operations, as well as [...] emissions," which is important because "autonomy needs to be combined with sustainable energy sources."

Participants think that this scenario will "synchronise well" with the roadmap, perhaps even "increase the speed of change" and the speed of "technology development," effectively "shift[ing it to an earlier point in the timeframe]" as there could be "earlier adoption" of technology. A driver of this would be when "AI" gets integrated across the "whole supply chain" that is used to enhance "planning" and connectivity in society.

Scenario 2: Circle Back

The sustainability and circularity hype went through the roof. A digital global government was launched to tax goods by their distance travelled. Revenues were used to subsidise renewable electricity, urban farming, and local production of goods. Vacations are taken at enhanced virtual experience resorts.

Participants' assessment

Participants elaborated on this scenario by explaining how "a very strong wish for a sustainable future" "would [reinforce] more smart [and] conscious consumption". The impact of a circular mindset would mean that consumers would begin "pushing for quality over quantity." Participants imagined an uptake in "local production and nearshoring" that would "reduce cargo," with the implication that "efficiency and size will be of less importance."

Respondents indicated that this scenario results in "reshuffling the axis of power, and the way business is done today would change drastically." "Less demand for transportation of goods" and "[workforce]," would lead to an "imbalance between supply and demand of ships" to the extent that "fleeting operations [would occur] on the coast, [where they could double as] distribution centres."

Participants also anticipated "less investment in shipping fleet overcapacity." Shipbuilding would stagnate as ship lifespans would extend to "30 years on the water", as focus would shift to maintaining the existing fleet because "ships and equipment have to last longer," making "data driven and conditioned based maintenance and repair [...] essential." Investments and the "purchasing of new digital products [and] solutions would move slower forward," as would the "development for energy efficiency" practices, that effectively result in "slowing the speed of technological evolution." This would render "some parts of the road map [...] obsolete or not applicable," in particular, those that depended on "data sharing."

On the other hand, participants imagined that the developments of standards would speed up, for example, "standards for recycling of ships and equipment," and "infrastructure for [new] fuels." The upside for Ro-Ro shipping, however, might be that "lorries would be forced off the roads and onto vessels, [with more cargo] travelling on rail, barges and container feeders" and the implementation of "fare-distant" tax schemes. The benefits of "scaling" would benefit the environment to the effect of "cleaner waters" and lower "emissions."

Scenario 3: King Quality

Any goods or products accused of planned obsolescence were outlawed. Quality is king, and repairs and refurbishing of products became the shared responsibility of the entire value chain – from manufacturer, to transporter, to retailer.

Participants' assessment

Participants' responses were marked with a concern for global value chains. "Protectionism" could rise up to challenge "open economies" in this scenario. It would "potentially stress the current supply chains" where "Europe" would challenge its "specialised" shipbuilding industry that produced advanced and complex vessels, such as cruise ships.

This scenario will result in "removing less reusable products out of the market" as they have "become obsolete." Although there might be an increase of the sale of "spare parts," the overall implications of a "decrease [in] the demand for new products" will have an effect that "the need [for] shipping will be reduced." This, in turn, will lead to lower investments in technology, that will dampen the "technological momentum." But as we shall see, the value of data will increase.

In order to adapt to this scenario, a "mindset change for cheap to quality" would be required that would herald the "beginning of reverse logistics and all underlining re-X operations near the customer," and the "start of closed loop logistics thinking." It would be a scenario in which "green & return logistics will flourish."

In order to adapt to such a scenario, the shipping industry "will need more detailed monitoring data from the whole transport chain" in order to "trace the quality." Under these demands, "IoT will be further developed to meet condition based maintenance requirements" where "data driven maintenance and repair" and "service based supply strategies" "will be essential." In the end, one participant stated that "safety is equal to quality" and there will be "more emphasis on maritime safety".

Scenario 4: Fast and Cheap

Booming African and Latin American markets took globalisation and trade to new heights. Oil is cheap and in stable supply. The backlogged order book led to the opening of new yards in the global south. Outside Europe, environmental concerns were brushed away to focus on economic growth, much of which happened in the absence of regulation of the financial institutions. Speculative investments were justified by fanciful projections of profits.

Participants' assessment

Participants identified many issues in this scenario. A lack of oversight from the European Union, and inability of the IMO to embrace the economic growth agenda by developing nations could lead to catastrophic consequences for the climate. Elaborations were given that there would be "little incentive to adopt energy efficiency technologies." Shipowners flagging their vessels under convenient states would benefit from a cheap and steady supply of oil which would lead to "cheap and dirty transportation/shipping" practices and another that "after 5-10 years of this scenario there will be serious pollution and climate problems, leading to ecological disasters and Europe will go down and become less developed and losing to competition."

Many participants thought that this scenario would never happen, stating things like "existing strong economies will not allow Latin America and Africa to do business this way." "The IMO goal on CO2 reductions will be a major obstacle" for this scenario to occur, as it would be "against the UN path for the future [and it] violates UN SDGs, mak[ing] it challenging" and "would ruin the road on which we have put so much effort."

The scenario could lead to potential protectionism, escalation of tensions and disintegration of globalisation. The world fleet would potentially see a decline in new ship buildings as "cheap labour from Africa and [Latin] America will keep low cost crew and old vessels," to the detriment of clean shipping practices. Market forces will dominate the competition and innovation in this scenario in which eco-efficiency is deprioritised, to the tune that "only market forces will then drive innovation" there would be "no sharing of information [unless] it is absolutely necessary for the business."

Furthermore, "regulation and standards implementation will be delayed," or there would be "no standardisation" at all. Environmental enforcement would be carried out by flag states and port state authorities, and the EU could take over much of the role of the IMO as vessels trading within the block to assert compliance.

Scenario 5: A New Logic

Shipowners went all-in after full data oversight on ships. Anything that could be monitored was. A new logic formed:

● *(Efficient) shipowners pressured EU regulators to enforce with teeth*

● *The EU forced the hand of the IMO*

● *IMO forced the class societies*

● *Classes forced the hand of standards organisations to streamline the adoption of protocols from neighbouring industries.*

Non-compliance shot up, as did fines. The US and Chinese stepped-up pressure through trade restrictions. They encrypted and manipulated their data. Nobody trusts the data anymore.

Participants' assessment

Participants assessed this scenario as a precursor to intensified competition, as "good performing shipowners will outperform others to increase market share" to the extent that "only the efficient shipowners would survive." The larger shipping companies would use their access to more data to their advantage, as one participant sees the "massive opportunities for leveraging synergies across supply chains, competitors, etc."

Based on this, participants called the scenario itself into question "the efficient shipowners will probably pressure IMO not [the] EU." And that there were prospects for emboldening the international institutions, resulting in a "UN of Cyber Security" that would make the "monitoring and compliance easily implementable" under a new "agreement on standards for cyber security" and the creation of "a world police" that would enforce "very strict port-state-control" as well as stronger regimes for "regulation," "taxation," and "issuing penalties." In order to do this, participants suggested first steps: "More detailed data oversight has to have a broad global acceptance" and there is urgency for "an agreement on standards for cyber security." If that can be accomplished, then it could result in "shifting the roadmap [events earlier in the timeframe]" as "regulation is accelerated."

However, there were concerns that overcoming the cybersecurity challenge is possible, and if not, then participants foresee a "big problem" that there is "more and more data but less credibility on it," and we might expect that "IOT technology adoption to slow down" from that. Participants expect that the scenario may make "data sharing obsolete," that would entail that "technological knowledge" be "local[ised], rather

than 'clouded'," for example, when "shore support centres no longer can be trusted." This would entail reliance on "industry expertise [that] would increase salaries for experienced workers," where the "efficiency of the decision-making [would] now be based on the smart people and not smart technology."

Scenario 6: Ecosystems Rule the High Seas

Shipowners moved fast to lock-in partnerships that co-create technology and shared specialised data. The power of business ecosystems rule the high seas. Tough enforcement of regulations forced shipowners to open up their data. But data standards couldn't keep up. A piecemeal approach, where the regulators got the data requested, but couldn't do anything with it, failed. Frustrated and distrusting shipowners moved to their home flags to protect their data. Panama & Liberia lost all significance.

Participants' assessment

Participants' elaborations on the scenario stated that while "personal networks would flourish between owners" and "new consortiums would be created," the "smaller companies [would] have no possibilities to implement new technology cheaply" and "will be the losers in this scenario if they will not be able to integrate to some bigger ecosystem" as the "research" would "[benefit the] large consortiums." Also, big multinational shipowners" might be inclined to "operate in several / many different eco-systems."

Participants observed that this scenario would have an impact on world trade. It could be "disrupted," "reduced," or even "reversed." This would make international coordination more difficult, in that there would be "no standardisation" and "no global ecological goals."

Participants see that this scenario could challenge the purview of the roadmap, although "new technology can possibly be implemented faster by the members of the consortiums". The diffusion of technology is supported by global standards. It could make the roadmap irrelevant not for the industry as a whole, but only for those with a significant footprint to act on it.

Scenario 7: A failure of consumer-led enforcement

Scandals, conspiracies, and hoaxes dominated news media cycles. Trust disappeared. The IMO was defunded after a vote of no-confidence. A new wave of consumer-led monitoring and enforcement grew, but this movement was demotivated when the citizen enforcers were accused, themselves, of corruption. Security forces at bunker tank farms and other critical infrastructure ballooned as threats by environmentalist groups escalated.

Participants' assessment

Participants feared that this scenario would "not [be] an attractive development" where "trade will be expensive and difficult" and could even result in "complete chaos." "Without [the] IMO the shipping industry would be a wild world (or wild west)" stated one participant, "where only the strongest and most shameless would succeed." Another challenged the premises of the scenario, stating that "if the end consumer / the customer is not right economics textbooks will be rewritten!"

With such a "zombie apocalypse," everything "will slow down." "It will be everyone for themselves," resulting in a breakdown of the connections between the elements. New alliances will form, with the possibilities created during previous era downs they do not need to be geographically related.

Scenario 8: We didn't start the fire

War devastated the Middle East. The Suez Canal was closed a long time ago. Protectionism made cash the king, and the big companies with good liquidity, one-by-one, squeezed out the rest. 30.000 TEU vessels, with military drone escort, dominate the milk run. Short sea shipping now hubs at human-made offshore fortresses. The oligopoly blocked, and reversed, all regulations.

Participants' assessment

Oil prices would be "sky-high," making the transport of goods "too expensive" for longer transit routes, resulting in higher "bunker fuel consumption" and more cargo

shifting to "air transport and railroads." With ships of such size, there might be just "one ship per day," but these ships "can't be built… out of [nowhere]," but by a "big company already in place." This shift would come at the expense of smaller ones who would see "very tough times."

Many of the participants elaborated on how this scenario would change shipping routes. The Middle East would be "out of the picture." "Egypt would lose income from the Suez canal transits," making trips longer, as they would go around South Africa whereas the "Panama canal would raise its tolls." Likewise, "new shipping routes" such as "through the Arctic," via the "Northern Sea Route north of Siberia," the "Faroe Islands" and "Iceland and Greenland becom[ing] important transport hubs," resulting in "new environmental regulations in the vulnerable region."

Regulations and standards, however, would not be "globally decided," but rather defined by "winning companies" whose "[roles] and responsibilities" would "merge." There might be consolidation to the extent that "the same company will own everything, seamless[ly, with] no competition, [and the] owner of hub[s] would 'win'". These companies would "just make their own rules." Smaller companies "outside the oligopoly" would work to petition the "WTO and UN" for "better market access." The new trade routes would increase the importance of "short sea" shipping to link "communities." Companies like "Amazon" might try to re-open "shallow ports" that have been left unattended to by large vessels, raising the question, "will there be enough trade to live off [of] in a monopoly?"

This scenario might see production moved locally, "replac[ing] a lot of imported consumables," perhaps due to increased "protectionism" and lead to "a new way of living." This could increase the "imbalance between developed and developing worlds," but with regions like "Latin America and Africa" being supported even more in their development from countries like China.

"Eco-efficient solutions" would "be in fashion" and "quicken" because of these longer shipping distances to Asia." More important would be efforts in "fuel [consumption] reduction," including the "speed[ing] up" of the "development of new fuels" and "alternative" fuels. "Digitalisation and tech implementation" would be "lead" by "some (big and efficient) companies. New transit routes through the Arctic "would require new solutions for safety, digitalisation and infrastructure."

The roadmap would "be driven by the economy" rather than "global standardisation" and would see a "decrease" in the "development speed." The roadmap "as shown is based on democratic principles and should be changed when this is no longer the case."

Finally, one respondent asked, "What about COVID-19?"

Appendix: Methods

This report was developed as a part of the ECOPRODIGI WP4 on foresight. Foresight is widely used in public policy, industry, and research domains to generate knowledge about the future in order to be able to anticipate and plan for it. This appendix will briefly outline the contribution of a series of applied tools, primarily belonging to the domain of strategic foresight, that were used in connection with WP4. The methods deployed in the project integrate a horizon scanning in the front end, a modified consensus forecast and technology roadmapping in the middle, and scenario-based stress-testing on the back end. Most of the approach has been of a qualitative nature, but there are also quantitative elements.

Any approach to map the future is, by its very nature, interdisciplinary. As such, this report is primarily a product of a series of workshops, supported in the interim between by the post processing of the results, and preparation of engagement materials for each subsequent workshop.

Horizon scanning is the exercise of collecting and curating information and expectations about the future, that, when compiled, becomes a reference library of strategic intelligence. Humans are doing some form of scanning in our personal and professional lives every day—whether conscious about it or not. While Horizon Scanning often includes dynamic changes such as trends, in this report and in the work of ECOPRODIGI, horizon scanning was used to source discrete events expected to happen in the future, primarily 1) anticipated innovations 2) forthcoming policies, regulations, and standards, that are expected to impact Ro-Ro and Ro-Pax shipping in the future. This scanning activity was the result of desk research and interviews, and some were borrowed from the Interreg North Sea Region PERISCOPE project. This resulted in an extensive list of events that were then brought into workshops for assessment by the consortium partners. Those that garnered the attention of participants were developed further into venture concepts, or short descriptions of a discrete technology-market event that would result in a value-adding capability, or a policy event that would alter the rules of the industry in the future.

Discrete events that were deemed critical to the development of the industry were selected for the establishment of a forecast of their "time to accepted practice" or time to their "commercial availability." In workshops, these were presented to the consortium partners, who were asked to estimate when in the future they expect that the event would occur. Using the median of these guesses as the crowdsourced forecast, the events were placed on the roadmap to serve as an "anchor" in the roadmap, around which other elements could be organised and ideated. Subsequent workshops were used to re-assess the outputs from previous workshops and place a number of other discrete events resulting from interim horizon scanning, new ideas developed during the post-processing of the workshops, and

some were borrowed from the PERISCOPE project. Pictures of the roadmaps and videos of the presentations were taken to support in this content development.

The content was then moved online and shared across the consortium. The partners were asked to write 200 word descriptions of the different discrete events that described the problem that the technology was being applied to, and the current approach that industry actors are employing to accomplish the task.

By this time, the three different roadmaps had been developed in parallel, one for Ro-Ro and Ro-Pax logistics, one for vessel operations, and one for shipyards. However, a decision was made that resulted in that two roadmaps were merged (logistics and operations) into an integrated Ro-Ro and Ro-Pax operations roadmap, in order to provide a more comprehensive assessment of the future because they had been borrowing and co-developing content across the roadmap. The shipyard roadmap was also borrowing and co-developing content from the other roadmaps, but in the end, the audience and professionals that would use the shipyard roadmap was established to be quite separate from those that would be using the integrated Ro-Ro/Ro-Pax roadmap.

When the roadmap had stabilised, outstanding questions remained on how to engage and incorporate the perspectives of the wider industry ecosystem into the roadmap. A survey with questions on each element in the roadmap was developed to this end that asked respondents to assess "how many years from now" that the discrete events would become "accepted practice" or "commercially available." At first it was distributed to the project team in order to validate the event and its clarity, and then it was distributed to other stakeholders in the project as well as practitioners. The median date for each of the events was used to position each of the discrete events on the roadmap.

Scenario planning techniques were deployed across the workshops; the first to frame the problem, the second to develop the scenarios, and the third to use the scenarios to assess the robustness of the roadmap. Developed in the intuitive logics tradition,[1] initial frames for the scenarios were developed in desk research and interviews to focus on the identification of critical uncertainties that would be used to develop the scenarios. Supported by a professional facilitator of scenario planning techniques, pictures and videos of the scenarios and their developers were made in order to ease post-processing. After the workshop, the scenarios were condensed into a paragraph length, and brought into another workshop where participants would assess each scenario, one-by-one, and then respond to prompts asking about how the scenario would impact the roadmap. These answers were subsequently condensed and written up (see the section on the scenario stress test).

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[1] See Van der Heijden, K. (2011). Scenarios: the art of strategic conversation. John Wiley & Sons.

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