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CONSIDERATION OF OTHER CONCRETE PROPOSALS FOR CANDIDATE MEASURES

Digitalization as a tool to reduce GHG emissions in maritime transport

Submitted by Finland

SUMMARY

Executive summary:	This document provides an overview of the identified challenges and measures in implementing digitalization as a tool to reduce greenhouse gas (GHG) emissions in shipping, together with other measures. It is submitted to support the discussions with respect to the *Initial IMO Strategy on reduction of GHG emissions from ships* and the GHG emission reduction targets. The study is based on the interview survey of selected actors along the whole supply chain and literature review. It is focusing on interfaces between different actors of the maritime transport. The identified measures to enhance implementation of digitalization as an emission reduction tool in maritime transport are disclosed in the document.
Strategic direction, if applicable:	3
Output:	3.2
Action to be taken:	Paragraph 18
Related documents:	MEPC 74/WP.6, MEPC 74/7/10; MEPC 73/WP.5; ISWG-GHG 5/4/8 and ISWG-GHG 5/J/2

Introduction

1 Digitalization of the maritime sector has been of great interest in recent years for achieving enhanced safety, security, efficiency and environmental sustainability. Digitalization and further optimization of shipping activities also have major economic benefits.

2 According to previous estimates, digital enhancements of shipping operations can save up to between €100 billion and €300 billion annually in operating costs for EU industries. Furthermore, it has been evaluated that the benefits of digitalization in the logistics sector as a whole will globally be approximately €1,400 billion by 2025.

3 The aim of the study *Digitalization as a tool to reduce GHG emissions in maritime transport* is to examine digitalization as one of the tools to reach the International Maritime Organization's (IMO) 2050 goal to reduce GHG emissions from international shipping by 50% compared to the reference year 2008. The aim is to find out how different actors in the transport chain perceive the potential role of digitalization in emission abatement. Furthermore, this study explores the challenges and obstacles for digitalization of shipping and the whole maritime transport and examines possible solutions. The focus of the study is on interfaces between the different actors in the transport chain.

4 The study is based on a literature review and semi-structured interviews conducted among 22 actors. The interviewed parties were selected to represent different parts of the maritime supply chain, technology providers, authorities and academia. The interviews focused on understanding the challenges and current development trends regarding digitalization and its emission reduction potential.

General results

5 The numerous new solutions, platforms and standards are being developed to replace the current ways of information exchange with digital processes. The industry faces several challenges which slow down the deployment of digital and data-based solutions.

6 The main identified challenges hindering digitalization in shipping were the following:

.1 fragmented industry and disconnected supply chain;

.2 traditional, rigid and global industry;

.3 freight contract models and modes of revenue generation;

.4 established procedures and operational models;

.5 lack of investments in digitalization and other emission reduction measures;

.6 fear of disruption and guarding of the status quo;

.7 lack of know-how and technical obstacles;

.8 limited communication means and data transfer capacity;

.9 challenges with information security;

.10 lack of sharing of data and information; and

.11 lack of harmonized way of data sharing.

7 The importance of digitalization on GHG emissions reduction can be considered on two levels. Firstly, digitalization is recognized as a tool for efficient information gathering, exchange and analysis. On the second level, digitalization and data-based systems are anticipated to cause disruption in the existing maritime business models. This would mean more data- and service-based optimization of the whole supply chain and possibly drastic changes in the current roles and ownership models of the industry.

8 The data sharing along the supply chain on a platform-based structure, combined with machine learning algorithms and predicting analytics, were recognized as one of the important measures for emission reductions.

9 Significant emission savings could be achieved by optimization of the utilization of cargo carrying capacity, voyage of a ship and cargo handling in a port. Maritime ports act as digital links in the value chains of maritime logistics, especially regarding more accurate information on ship arrival times. Ports also act as transport hubs with connectivity to the surrounding hinterlands. The faster the operations of loading and unloading are executed in the port, the more time the ship has to optimize its voyage and speed. Just-In-Time arrival (JIT) to port minimizes time at anchorage and therefore allows lower voyage speed and creates emission savings. The wider use of JIT and voyage optimization requires development of the current freight contract models.

10 There is an urgent need for real-time and secure data transfer throughout the whole supply chain, which is partly lacking cost-efficient and reliable communication means. Varying data quality and its scattered locations are also obstacles for optimal utilization of data. A lack of data sharing along the supply chain is hindering data-based optimization efforts.

11 Different actors are approaching digitalization from their own angles instead of considering how the entire industry should be transformed by digitalization. Development of overlapping systems which do not interact creates yet another challenge to overcome. According to the report, the industry is strongly guarding the status quo.

12 Lack of progress in digitalization and optimization in shipping is not due to a lack of regulation. However, some standard formats of information exchange or mutually agreed Application Programming Interfaces (API) could be introduced.

13 The main measures to consider for overcoming the challenges in the further development are the following:

.1 Operational and institutional measures:

.1 focusing on the entire supply chain to ensure seamless transportation;

.2 creating incentives for voluntary data sharing;

.3 developing freight contracts with new sustainable clauses to enhance optimal sailing speed and Just-In-Time arrival;

.4 converting waiting time in ports to sailing time at sea through more real time data;

.5 promoting innovative public procurements; and

.6 promoting discussion on digital disruption and creating a common understanding of the importance of digitalization in the maritime industry.

.2 Global harmonization of information sharing:

.1 enabling submission of all administrative information from a ship through one input point (single windows), cutting out overlapping systems; but avoiding centralized systems;

.2 providing real-time access to authority/public data (e.g. transportation data);

.3 developing standardized ways for ships to communicate with ports globally and harmonizing descriptions of Application Programming Interfaces (APIs); and

.4 sharing selected data combined with electronic identification in interfaces.

.3 Technical measures:

.1 promoting the development of platforms that enable trust among stakeholders, interoperability and decentralized data sharing and service-based business models and machine learning; and

.2 developing affordable technical means for ship-to-shore connectivity and sharing of real-time data.

14 It would be beneficial to include digitalization and data sharing in both short-term and mid-term emission abatement measures to reach IMO's Initial GHG Strategy.

15 There are already several studies on challenges of digitalization that should be taken into consideration. Further examination of actions needs to be developed and taken. Understanding how the entire maritime transport system will develop in the future is fundamental in defining emission reduction measures. Instead of single energy-efficiency measures, the scope of discussion among regulators and the whole industry should be wider.

16 The full text of the study is provided in annex to this document.

17 The work that is in the scope of other IMO committees should also be fully taken into consideration, for example the IMO FAL single window concept, its application and harmonizing data models.

Action requested of the Working Group

18 The Group is invited to take note of the information provided in this document and to take action as appropriate.

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Finnish Transport and Communications Agency

Digitalization as a tool to reduce GHG emissions in maritime transport

Executive summary

Digitalization of the maritime sector has been of great interest in recent years for achieving enhanced safety, security, efficiency and environmental sustainability. Digitalization and further optimization of shipping activities have also major economic benefits.

The aim of this study is to examine digitalization as one of the tools to reach the International Maritime Organization's (IMO) 2050 goal to reduce GHG emissions from international shipping by 50 % compared with reference year 2008. The aim is to find out how different actors in the transport chain perceive the potential role of digitalization in emission abatement. Furthermore, this study explores the challenges and obstacles for digitalization of shipping and the whole maritime transport and examines possible solutions. The focus of the study is on interfaces between the different actors in the transport chain.

The study is based on a literature review and semi-structured interviews conducted among 22 actors. The interviewed parties were selected to represent different parts of the maritime supply chain, technology providers, authorities and academia. The interviews focused on understanding the challenges and current development trends regarding digitalization and its emission reduction potential.

According to previous estimates, digital enhancements of shipping operations can save up to EUR 100-300 billion annually in operating costs for EU industries. Furthermore, it has been evaluated that the benefits of digitalization in the whole logistics sector will globally be ca. EUR 1 400 billion by 2025.

Numerous new solutions, platforms and standards are being developed to replace the current ways of information exchange with digital processes. Based on the study, the industry faces several challenges which slow down the deployment of digital and data-based solutions. The main identified challenges hindering digitalization in shipping, as well as identified measures to overcome them, are discussed in the report.

The importance of digitalization on GHG emissions reduction can be considered on two levels. Firstly, digitalization is recognised as a tool for efficient information gathering, exchange and analysis. On the second level, digitalization and data-based systems are anticipated to cause disruption in the existing maritime business models. This would mean more data- and service-based optimization of the whole supply chain and possibly drastic changes in the current roles and ownership models of the industry.

Data sharing along the supply chain on a platform-based structure, combined with machine learning algorithms and predicting analytics, was recognised as one of the important measures for emission reductions. Some of the interviewed parties regarded the use of artificial intelligence (AI) crucial for predicting cargo flows. In order to gather and utilize data, it is essential to develop the data flow from ship to shore, ship to ship and shore to ship.

Significant emission savings could be achieved by optimization of the utilization of cargo carrying capacity, voyage of a ship and cargo handling in a port. Maritime ports act as digital links in the value chains of maritime logistics, especially regarding more accurate information on ship arrival times. Ports also act as transport hubs with connectivity to the surrounding hinterlands. The faster the operations of loading and unloading are executed in a port, the more time the ship has to optimize its voyage and speed. Just-In-Time arrival (JIT) to port minimizes time at anchorage and therefore allows optimal voyage speed and creates emission savings. Wider use of JIT and voyage optimization require development of the current freight contract models.

There is an urgent need for real-time and secure data transfer throughout the whole supply chain, which is partly lacking cost-efficient and reliable communication means. Varying data quality and its scattered locations are also obstacles for optimal utilization of data.

Furthermore, a lack of data sharing along the supply chain is hindering data-based optimization efforts.

Different actors are approaching digitalization from their own angles and how they as a company could benefit from it, instead of considering how the entire industry should be transformed by digitalization. Development of overlapping systems which do not interact creates yet another challenge to overcome. The industry is also strongly guarding the status quo. However, new data-based business models might change the current division of processes and tasks in the supply chain.

According to this study, the lack of progress in digitalization and optimization in shipping is not due to a lack of regulation. The interviewed parties see that regulation is not the main way forward to enhance digitalization. However, some standard formats of information exchange or mutually agreed Application Programming Interfaces (API) could be introduced.

As a conclusion, further examination of challenges hindering the implementation of digitalization and development of measures to overcome them are required. Understanding how the entire maritime transport system will develop in the future is fundamental in defining emission reduction measures. Instead of single energy-efficiency measures, the scope of discussion among regulators and the whole industry should be wider.

Furthermore, in the light of the results of this study, it would be beneficial to include digitization to be one of the both short-term and mid-term emission abatement measures to reach IMO’s Initial GHG Strategy.

The study has been subcontracted from Wega Group Ltd by the Finnish Transport and Communication Agency, Traficom. Responsible consultants were Aino Rantanen, MSc, Nora Berg, MSc, and Eija Kanto, PhD. The study was conducted in June - September 2019.

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1 Background and Introduction

Over 90 % of the world's trade is carried by sea and maritime transport is the backbone for global trade. Shipping is the most efficient and cost-effective method for international transportation of goods.

According to the third IMO's GHG study[1], international shipping emitted 796 million tonnes of carbon dioxide (CO_2) in 2012, accounting for about 2.2 % of the total global anthropogenic CO_2 emissions for that year. It is estimated that emissions from international shipping could grow between 50 % and 250 % by 2050 mainly due to the growth of the world maritime trade. The forecasted demand for maritime transports will increase with 60 % by 2050 with the pace of growth being highest up to 2030 and with significant differences between the various shipping segments[2]. Therefore, shipping can play an important role in reaching the global GHG emission reduction goals.

International shipping and aviation were excluded from the Paris Agreement[3] (2015), and UNFCCC gave a mandate for the International Civil Aviation Organisation (ICAO) and IMO to set targets and goals by themselves to decrease GHG emissions from their respective sectors.

The energy-efficiency requirements of ships have been introduced as amendments to MARPOL[4] Annex VI and the initial IMO strategy on the reduction of GHG emissions from ships[5] has been adopted. However, shipping as an industry suffers from systemic inefficiencies that result in slow adaption of emission abatement and digital tools. The shipping industry has not yet capitalized on the full potential of new technology and communication tools[6].

Digitalization and automation of shipping and cargo operations can help to reduce emissions together with other measures. GHG emissions could be reduced by operational measures, smoother ship-port interfaces and by using larger vessels that could carry more freight in relation to used energy. Furthermore, emissions will be reduced when changing from traditional fossil fuels gradually to alternative fuels and renewable sources of energy. Alternative fuels and propulsion technologies include e.g. wind power, battery technology and biofuels. In addition, the interest in using hydrogen as a fuel solution is growing.

1.1 Ship energy efficiency requirements and data collection systems

The existing regulations on CO_2 emissions in the MARPOL convention include two main measures. The Energy Efficiency Design Index (EEDI) refers to new buildings designs whereas the Ship Energy Efficiency Management Plan (SEEMP) is for management of ship energy consumption and emissions[7].

The IMO's Data Collection System (DCS) is adopted as amendments to MARPOL Annex VI and has been effective from 1 January 2019. DCS is used to collect and report fuel oil consumption of ships[8]. The system is integrated to the SEEMP, which should include a description of the methodology that is used to collect the data and of the process to report the data to the ship's flag state. 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 state after the end of each calendar year. The flag state is required to subsequently transfer this data to the IMO Ship

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[1] IMO 2014. Third IMO GHG Study
[2] DNV GL 2017. Maritime Forecast to 2050
[3] United Nations 2015. Paris Agreement
[4] IMO. International Convention for the Prevention of Pollution from Ships. Accessed_10/09/2019
[5] IMO 2018. Initial IMO Strategy on Reduction of GHG Emissions from Ships
[6] Gustafsson, M. et al. 2019. Driving Emission Out of Shipping, A race against time. White Paper. Åbo Akademi, PBI Research Institute.
[7] IMO 2011. Energy Efficiency Measures
[8] IMO 2016. Data collection system for fuel oil consumption of ships

Fuel Oil Consumption Database. IMO Secretariat is required to produce an annual report to the Marine Environment Protection Committee (MEPC), summarizing the data collected.

Parallel to the IMO's DCS, the European Union has developed a flag neutral system for monitoring, reporting and verification (MRV) of CO_2 emissions from large ships using EU ports[9]. From 1 January 2018 onwards, large ships over 5 000 gross tonnage, regardless of flag or country of ownership, loading or unloading cargo or passengers at ports in the European Economic Area (EEA), are to monitor and report their related CO_2 emissions, and other relevant information, such as fuel consumption, distance travelled, time at sea and cargo carried on a per voyage basis. A monitoring plan is obligatory for each complying ship, and the reported CO_2 emissions are verified by independent certified bodies and sent to a central database managed by the European Maritime Safety Agency (EMSA, THESIS-MRV).

1.2 Initial IMO Strategy on reduction of GHG emissions from ships and the follow-up measures

In 2018, IMO adopted an initial strategy on reduction of GHG emissions from ships[5], to be complemented by a more developed strategy in 2023. The initial strategy sets out a vision which confirms IMO's commitment to reducing GHG emissions from international shipping. There is a clear ambition to pursue efforts towards phasing out GHG emissions entirely by the end of this century.

The strategy envisages a reduction in carbon intensity of international shipping. The CO_2 emissions per transport work, as an average across international shipping, should be reduced by at least 40 % by 2030, pursuing efforts towards 70 % by 2050, compared with 2008. The total annual GHG emissions from international shipping should reach their peak as soon as possible and be reduced by at least 50 % by 2050 compared with 2008 whilst pursuing efforts towards phasing them out.

The strategy represents a framework for Member States of IMO, setting out the future vision for international shipping, the levels of ambition to reduce GHG emissions and guiding principles, and includes candidate measures with possible timelines and their impacts on States. The strategy also identifies barriers and supportive measures including capacity building, technical co-operation and research and development. The strategy notices that technological innovation will be integral to achieve the overall ambition.

The candidate measures to reduce GHG emissions are divided in short-term (finalized and agreed between 2018 and 2023), mid-term (2023-2030) and long-term (beyond 2030) measures. The short-term measures include inter alia:

- considering and analysing the use of speed optimization;
- considering and analysing measures to encourage port developments and activities globally to facilitate reduction of GHG emissions from shipping, including to further optimize the logistic chain and its planning, including ports;
- initiating research and development activities addressing innovative technologies to further enhance the energy efficiency of ships; and
- incentives for first movers to develop and take up new technologies.

The 73rd session of the Marine Environment Protection Committee (MEPC) approved a follow-up programme[10], intended to be used as a planning tool in meeting the timelines identified in the initial strategy. Furthermore, the 74th MEPC session adopted resolution MEPC.323(74)[11] on Invitation to Member States to encourage voluntary co-operation between the port and shipping sectors to contribute to reducing GHG emissions from ships. This could include

[9] EU 2015. Regulation on the monitoring, reporting and verification of carbon dioxide emissions from maritime transport

[10] IMO 2018. Next steps to deliver IMO GHG strategy

[11] IMO 2019. Draft MEPC resolution that invites Member States to encourage voluntary cooperation between the port and shipping sectors to reduce GHG emissions from ships

regulatory, technical, operational and economic actions, such as incentives promoting sustainable low-carbon and zero-carbon shipping, and support for the optimization of port calls including facilitation of Just-In-Time (JIT) arrival of ships.

The aim of this study is to examine digitalization as one of the tools to reach the International Maritime Organization's (IMO) 2050 goal to reduce GHG emissions from international shipping by 50 % compared with reference year 2008. The aim is to find out how different actors in the transport chain see the potential role of digitalization in emission abatement. Furthermore, this study explores the challenges and obstacles for digitalization of shipping and the whole maritime transport and examines possible solutions. The focus of the study is on interfaces between the different actors in the transport chain.

2 Material and Methods

The study is based on a literature review and semi-structured expert interviews held with 22 different actors along the maritime transport chain (Table 1 and Appendix 1). One of the interviewed shipowners also acts as a port operator and responded to the questions also from an additional point of view. Therefore, the total amount of interviewees is 23. The interviewed parties were selected to represent the different supply chain actors, technology providers, authorities and academia. Interviews were conducted in June-August 2019. The interviews were conducted face-to-face when possible, otherwise by online meeting, phone or e-mail.

Table 1. The shipping stakeholders interviewed in this study.

Interviewed party	Number of interviews
Cargo owner	2 interviews
Agent/forwarder	1 interview
Ports & port associations	3 interviews
Port operators	1 interview
Shipping/maritime organizations	5 interviews
Authorities	3 interviews
Academia	1 interview
Technology and digital system providers	6 interviews
TOTAL	**22 interviews**

The aim was to interview actors across the maritime transport chain, covering at least one interviewee per group. Therefore, the interviewed actors were selected from different parts of the chain, from technology providers and digital solution start-ups to authorities and academia working in the maritime transport sector. Land carriers were excluded due to time constraints. In the following chapters, the views of the authorities and academia are combined, to not reveal the views of individual interviewees, and because neither of these groups have a direct financial interest in the field of this study.

During the interviews, possible emission reduction measures via digitalization were discussed. The interviewees were asked how they see digitalization in terms of emission abatement. The proposed measures were categorized as operational/institutional measures and technical measures. The need for standardized means of information exchange as a measure for GHG reduction was asked distinctly.

The key questions of the interviews are listed in Appendix 2. Depending on the interviewed person and the operations he/she was representing, more detailed follow-up questions were asked within this key framework.

3 Results and Discussion

3.1 The role of digitalization in maritime transport

According to the Finnish Governmental Resolution[12], Artificial Intelligence (AI), big data and Internet of Things (IoT) will bring knowledge management into the field of logistics. Compared with other transport sectors, shipping still relies mostly on old manual systems and data sharing and use of digital systems are not yet the norm. The logistics sector has not made any remarkable progress in terms of digitalization compared with the situation a decade ago due to lack of change innovation drivers in the sector[13]. However, existing information systems contain almost all information needed, but the challenge is to integrate the information and to check its reliability and validity[14]. Another challenge is the lack of trust between the actors to share data.

Digitalization is considered to influence the maritime industry on two levels. Firstly, digital data enables optimizing ships' operational and energy efficiency and significantly improves the exchange of information between different actors. Collecting and sharing of digital data enables optimization of operations in the whole supply chain. Gathering and sharing digital data is also a prerequisite for automatization of operations. Secondly, business models in shipping and the overall concept of how ships are operated might be changed due to digitalization. This will have an impact on energy usage. Traffic, port logistics and JIT arrival will change as an electronic revolution takes place with data and networking of technologies[15]. Digital technologies will ensure shorter waiting times for ships and faster processing in terminals[16]. Also, optimized voyages by adapting navigation according to real-time weather, wind and ocean current data will lead to decreases in energy consumption. For example, integration platforms and machine learning could be used to collect operational ship data from system suppliers[14] [17] [18]. This requires that the systems utilize standardized data formats. The use of IoT sensors on board ships to proactively monitor possible system errors can also reduce the need of flying in technicians to ships to fix errors and spare parts to a ship in transit. Smart container technologies and real-time tracking of cargo by Global Positioning System (GPS) and other information and communication technologies (ICT) will increase the transparency on the transport route from the sender to the recipient.[19] Digitalization can be used in ports to handle future challenges such as capacity bottlenecks, issues of accessibility, and environmental challenges by involving analytics to forecast arrival and waiting times and to identify errors in the supply chain.

The usage of blockchain technology has been of growing interest in digitalization of the supply chain. A blockchain is a decentralized, distributed and public digital ledger that is used to record transactions across many computers so that any involved record cannot be altered retroactively without the alteration of all subsequent blocks. This allows the participants to verify and audit transactions independently and relatively inexpensively. According to a case

[12] Finnish Government 2018. Resolution on the enhancement of digitalization in the transport and logistics sectors.
[13] Transport Intelligence 2019. Global Freight Forwarding 2019.
[14] Heilig, L. & Voss, S. 2017. Status quo and innovative approaches for maritime logistics in the age of digitalization: a guest editors' introduction. Information Technology Management 18: 175.
[15] Berg, D., & Hauer, M. 2015. Digitalisation in shipping and logistics. Asia Insurance Review 52.
[16] Lee, S.Y. et al. 2016. Port e-Transformation, customer satisfaction and competitiveness. Maritime Policy & Management 42(5): 630-645
[17] Grucza, D. 2017. Industry 4.0 on the High Seas. Maritime reporter and engineering links. Accessed 15/07/2019.
[18] Grucza, D. 2017. Industry 4.0 on the High Seas. Maritime reporter and engineering links. Accessed 15/07/2019.
[19] Fruth, M. & Teuteberg, F. 2017. Digitalization in maritime logistics—What is there and what is missing? Cogent Business & Management 4:1.

study of enhancing information sharing in a Finnish Port community by using blockchain technology, knowledge and applications of blockchain are still few.[20]

Digitalization and optimization can also result in major economic benefits. It is estimated that digital enhancements of shipping operations can save up to EUR 100-300 billion annually in operating costs for EU industries. The digitalization of logistics of goods will result in an estimated decrease of 15-30 % in CO_2 emissions of the EU transportation sector[12]. Furthermore, the World Economic Forum has evaluated that the benefits of digitalization in the logistics sector will globally be ca. USD 1 500 billion by 2025[21].

3.1.1 Examples of maritime digital solutions

There are countless of digital solutions and initiatives already in use and under development. Some of the systems and development ideas are described below as examples.

IMO has defined the concept of e-Navigation to be "a harmonized collection, integration, exchange, presentation and analysis of marine information onboard and ashore by electronic means to enhance berth to berth navigation and related services and protection of the marine environment". The e-navigation Strategy Implementation Plan (SIP) was approved in November 2014[22].

Container lines have collaborated on digital initiatives and started to develop common standards recently. Digital Container Shipping Association[23] is an alliance to develop information technology and security standards to address common challenges in the information exchange. Maersk has succeeded in getting CMA CGM, MSC, Hapag-Lloyd and Ocean Network Express to join its TradeLens platform. The goal is to digitize the flow of documents in container freight by using e.g. blockchain technology[24]. TradeLens was launched to help modernization of the world's supply chain ecosystems. Many of the processes for transporting and trading goods are costly partly due to manual and paper-based systems. The platform enables participants to digitally connect, share information and collaborate across the shipping supply chain. Managing the uncertainty of when ships will be served during a port visit would enable higher fleet and capacity utilization generating substantial benefits for all actors in the global transport chain.[25]

There are several start-ups working with different digital and AI solutions for the interaction between ship and shore. One of them is NauticAI, a start-up focusing on real-time situational awareness solutions. The aim of the company is to connect ships and real-time data in a device-independent way and to reduce the information friction between the parts in the maritime information exchange chain. The idea is to connect correct information to correct parties with custom made, visual real-time awareness solution service.[26]

KNL Networks provides solutions for maritime connections in the form of IoT and platform services and vessel tracking using high-frequency (HF) radio technology supported by satellite and mobile communication networks. KNL provides reliable and affordable connectivity through a dedicated HF based mesh-network with high security. KNL offers global access to data by integrating into onboard systems and collecting and processing needed and relevant data, sending it via global Wave Access shortwave radio mesh network. The collected data is made available for the users through the KNL Cloud where it can easily and securely be retrieved for

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[20] Tähtinen, E. 2019. Blockchain technology to enhance information sharing in a port community Case: Vuosaari Harbour, Port of Helsinki. Unpublished master's thesis, University of Turku.
[21] World Economic Forum 2019. White Paper on Inclusive Deployment of Blockchain for Supply
[22] IMO 2019. E-navigation. Accessed 21/08/2019
[23] Digital Container Shipping Association. Accessed 10/09/2019
[24] Maersk 2019. TradeLens blockchain-enabled digital shipping platform continues expansion with addition of major ocean carriers Hapag-Lloyd and Ocean Network Express. Accessed 09/09/2019
[25] Lind et al. 2019. Substantial value for shipping found in Port CDM testbeds. Accessed 09/09/2019
[26] NauticAI. Accessed 13/08/2019

further processing and analysis. KNL believes that better communications will be the key for fuel consumption optimization, emission control and usage of any digital services.[27]

NAPA provides software, services and analytics for shipping. NAPA's intelligent solutions aim at increasing safety, efficiency and productivity in both ship design and operations. NAPA's solutions for ship operations help in monitoring, planning, analysing and optimizing safety, stability and performance for a vessel or a fleet. NAPA combines analytical and big data tools with easy to use record-keeping and data management software. For example, NAPA Fleet Intelligence combines a variety of data sources with highly accurate ship performance models to create insights and advice for improved performance.[28]

Kongsberg maritime is a Norwegian shipping company and service provider that offers technological solutions related to seafaring and shipping. The company operates more than 18 000 ships globally. Kongsberg has introduced cloud-based open digital solutions to help in the integration and sharing of data. Kongsberg works e.g. with energy management and remote operations of vessels and provides sensor technology for ships, technology for traffic management and ship intelligence solutions.[29]

More and more digital platforms for shipping are being developed. Half of the shippers use an online platform and ca. 20 % of freight will be covered by these in 2023[13]. These digital forwarding platforms are quickly growing and include applications from online booking to digital "control towers".

A start-up called Seaber is an independent platform provider that supports direct communication between shipowners, charterers and other stakeholders to improve operational efficiency. The company is currently doing pilots with several Northern European companies. Seaber system integrates data from multiple sources and digitalizes monitoring and communication between shipowners, charterers, port agents, brokers and other stakeholders to improve operational efficiency. Seaber platform is currently targeted to short-sea shipping of dry bulk cargo in Northern Europe. Through the platform, a cargo owner or shipping company can optimize its operation and look for the most optimal way to transport cargo and to combine transportations. By using the platform, a shipping company can optimize the use of its vessels and a cargo owner can find optimal vessels and routes for transporting. Use of Seaber platform can also save time in the port (ca. 1-2 hours/port call) through optimal change of information and better knowledge of arrival and departure times.[30]

Another start-up called AWAKE.AI is aiming to create a platform for smart ports and autonomous ships. The company develops open service predicting analytics and machine learning models to operators in the maritime sector. AWAKE.AI brings solutions for optimizing port and ship operations. AWAKE.AI offers platform-based information sharing and machine learning, which can be used for forecasting as well. AWAKE.AI creates new digital interfaces to places where there is still manual change of information. The solution solves currently existing challenges and contributes to the development of autonomous shipping and enables autonomous ships to call at ports.[31]

There is also a lot of on-going work related to standardized communication between ships and ports. The Sea Traffic Management (STM) Validation project is a European initiative under the EU's Motorways of the Sea umbrella. STM Validation project ended in July 2019 and focused on implementing new digital information exchange services for shipping and port industries. STM is a concept for sharing secure, relevant and timely maritime information among authorized service providers and users. This is done by a common framework and common standards for information and access management. Interoperability between actors is achieved by specifying not only what format the data should have but also how the data exchange should be done.

[27] KNL Networks. Accessed 14/08/2019
[28] NAPA. Accessed 12/08/2019
[29] Kongsberg. Accessed 12/08/2019
[30] Seaber. Accessed 17/06/2019
[31] AWAKE.AI. Accessed 14/08/2019

Four implementation projects have commenced after the completion of STM Validation Project.[32]

The Port of Rotterdam has recently launched the company PortXchange to promote the Pronto digital platform service offered to ports, shipping companies and terminals. The aim of the company is to improve the efficiency of port calls and help their clients in reducing emissions with a joint platform enabling optimal planning, execution and monitoring of port call activities[33]. The Port of Oulu, Finland, is currently working on the development of a digital, real-time port infrastructure system platform in order to establish a real-time digital picture of the port to benefit the whole port community[34].

3.2 Information flow in the maritime transport chain

Total seaborne trade volumes reached 10.7 billion tonnes in 2017, of which the top 20 global ports handled 9.3 billion tonnes. 752.2 million TEU[35] were moved at container ports worldwide in 2017. The world commercial fleet consists of almost 100 000 vessels[36]. The world fleet is registered to over 150 nations and manned by over a million seafarers of virtually every nationality[37].

Maritime transport can be roughly divided into short-sea and deep-sea shipping, both with typical characteristics, including information flow and digitalization. Short-sea or coastal shipping means short distances serviced by small vessels. Short-sea shipping often competes directly with land-based transports. Deep-sea shipping is the transportation of commodities in longer distances mainly crossing an ocean and is usually operated by bigger vessels (i.e. Supramax, Panamax, Post-Panamax, Capesize) in order to achieve economies of scale[38].

Maritime industry is very fragmented with high number of different actors and companies. Due to the global context and long history of seafaring, the maritime transport chain is complex and includes several stages depending on the type of goods and the route the freight is travelling. The different actors involved in maritime transportation vary depending e.g. on freight type, scope of the companies involved in the transportation and the geographical area in question. Fragmented nature of maritime transport chain causes inefficiency.

The key actors within the maritime transport chain are the shipping companies, the ports and the different types of terminals. Majority of global shipping companies are small with operating fleet of less than five ships.[6] The ship investment is long-term as the average operating age of a ship is 25-50 years.

Maritime ports are hubs for the flow of goods and people connecting land, passengers and maritime transports[39]. There are some 800 most active maritime ports globally and an additional couple of thousand smaller ports[40]. The faster the operations of loading and unloading in the port are, the more voyages can the ship make and the more effective is the logistics chain. Another important factor for ports as transport hubs is their connectivity with the surrounding hinterlands. This requires interaction and collaboration between numerous businesses and public sector administrative units, e.g. national customs and transport

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[32] Swedish Maritime Administration 2019. Sea Traffic Management Validation Project, Final Report.
[33] Port of Rotterdam. Port of Rotterdam Authority launches new company PortXchange to make digital shipping app Pronto available to ports worldwide. Accessed 04/09/2019
[34] Port of Oulu. PORT OULU Smarter. –digihankkeen toteutusvaihe starttaa! Accessed 04/09/2019
[35] twenty-foot equivalent unit
[36] United Nations Conference on Trade and Development 2018. Review of Maritime Transport 2018. UNCTAD/RMT/2018
[37] International Chamber of Shipping. Accessed 09/09/2019
[38] OpenSea. Pro, Blog: Dry Bulk Market: Shall We Trade Short Sea or Deep Sea? Accessed 19/08/2019
[39] Posti, A. et al. 2010. Satamayhteisön informaatiokeskus tiedonvälityksen tehostajana. Publications from the Centre for Maritime Studies, University of Turku 175.
[40] Seaports of the World. Accessed 28/08/2019

authorities[41]. Therefore, the role of ports in the digitalization of the maritime transport chain is of utmost importance.

Recent analysis of shipping movements in nine European ports identified that cargo vessels spent only 60-70 % of their port time at berth and only 40-65 % of berth time was used for operations. On average, container ships in a harbour spent ca. 70 % of their time at berth, while only 58 % of their time was spent doing operations.[25]

The flow of goods from the manufacturer to the end user is described in a supply chain. In the chain, the flows of material, information and money need to be managed simultaneously. Understanding the whole process and the roles of the numerous actors is needed to find the critical interfaces where digitalization could potentially be utilized to increase efficiency of the entire chain and thereby reduce related emissions.

Information exchange in the supply chain is quite complex and multi-phased. Figure 1 shows an example of information interfaces among different actors in a supply chain from the cargo shipper to the cargo receiver. Compared with other transportation modes, there are several intermediate parties, such as forwarders and agents, involved. The means of communication vary from paper documents, phone and e-mail to digital information systems.

[41] Inkinen, T. et al. 2019. Port Digitalization with Open Data: Challenges, Opportunities, and Integrations. J. Open Innov. Technol. Mark. Complex. 5:30.

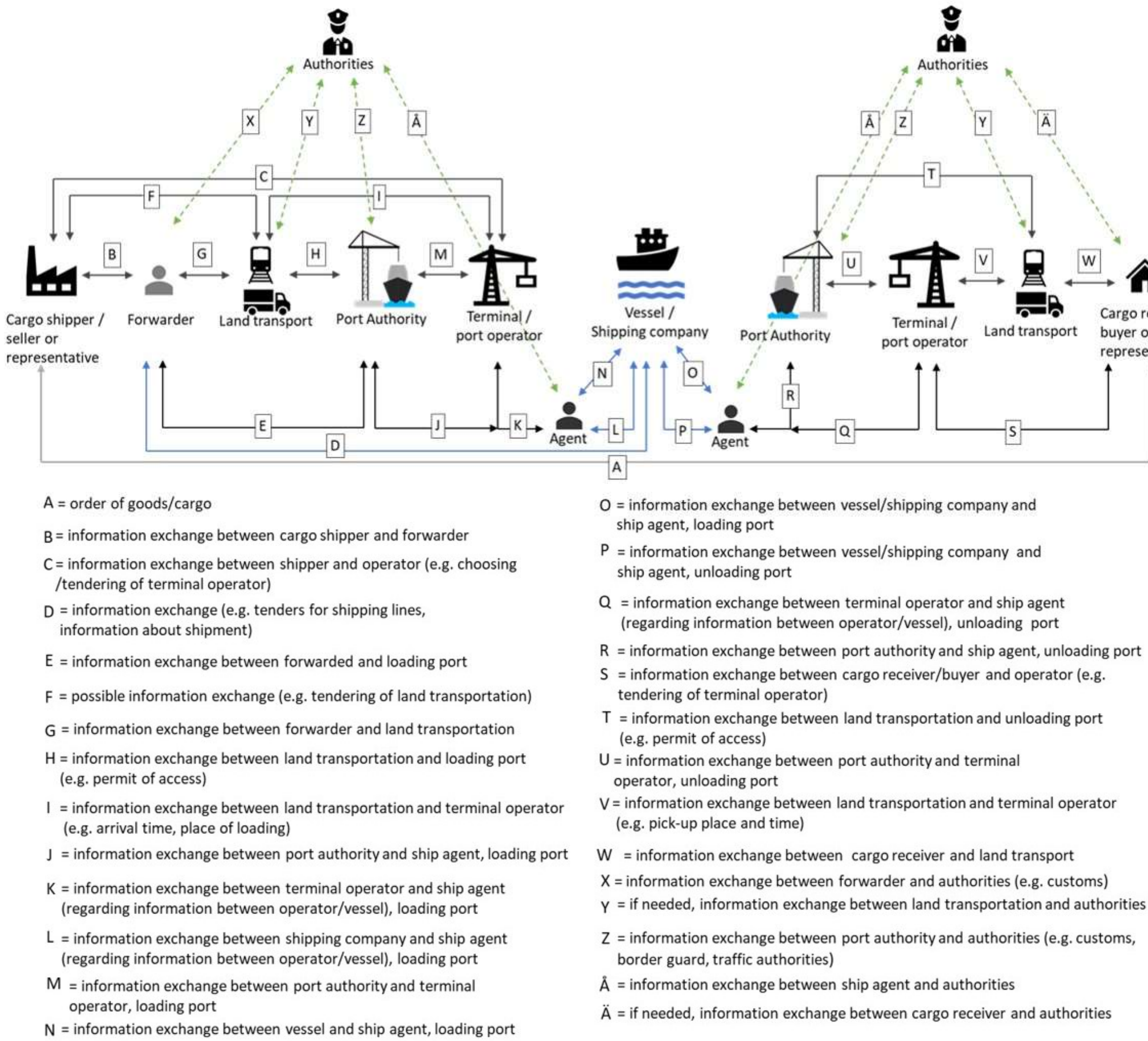

Figure 1. Example of the supply chain and information interfaces compiled by the authors.

In addition to the above-mentioned information flow and information interfaces, there are different protocols related to the required documents in different types of freight transportations. These protocols vary depending on e.g. cargo type and the division of responsibilities in each case.

3.2.1 Exchange of information in a port

Typically, there are several parties involved in port operators since usually the port and operators are different companies, and a lot of information is exchanged among them. The flow of information can be divided into obligatory information provided to authorities and into exchange of information between private companies. Some of the actors have automated and digitalized their processes whereas some of the organizations still rely on more traditional means such as paper, pen and telefax.

The required documents vary depending on a port of call. Usually the ship agent is provides the required documents. The so-called pre-arrival documents include dozens of documents such as crew and passenger lists, general declarations, descriptions of cargo, information of voyage, cargo declarations, and dangerous goods declarations. Some of the documents can be directly submitted to EU through national Single Window systems. During this study, the single window system SafeSeaNet-Norway[42] was mentioned as a good example of a well working joint platform for information exchange at a Norwegian port for different stakeholders.

Some ports have implemented Port Community Systems (PCS) to solve bottlenecks in information exchange such as slow communication techniques, large number of documents and messages and the incompatibility of working procedures. PCS has mostly been implemented in large ports such as the ports of Singapore, Hamburg and Rotterdam. The advantages of these systems have been indisputable: processes are faster and less complex, paperwork and errors decrease significantly, transparency of data increases, planning becomes easier and reacting to disturbances becomes faster. The South Korean national PORT-MIS system has saved ca. USD 100 million annually[39].

The usage of e-mail in information exchange within the port community poses some challenges related to the management and archiving of messages, processing time, limited size of attachments, and their incompatibility with operative systems. Also, the vulnerability of e-mail systems is often not considered at all when exchanging commercially sensitive information.

Moreover, most of the port related information is currently exchanged bilaterally between two parties. Therefore, the same information needs to be communicated separately to several parties so that all actors can utilize the information in their operations. The shipping company usually communicates deviations in the ships' estimated time of arrival (ETA) to the port operator, but the information may not reach other actors such as the carrier collecting the goods. This hinders efficient planning of port operations by different actors.[39]

Maritime ports act as a digital link in the value chains of maritime logistics due to the development of digitalization application to offer more accurate ship arrival times and real time cargo tracking and visibility[20]. Having more accurate arrival times also allows ports to manage port congestion better and plan the needed capacity for efficient cargo handling.

3.2.2 Exchange of information at sea

While at sea, the ship is constantly in contact with several actors (Figure 2). Communication is done via radio (Very High Frequency VHF/ High Frequency HF) and satellite systems, such as Inmarsat20 (phone or e-mail). Even with faster satellite connections, ships can still be regarded as disconnected islands when out in the open seas. Currently all the communication, from the leisure usage of the crew to business-critical navigational data by the ship, is normally done via the same satellite connection and submitted through the same narrow bandwidth, which poses a challenge in terms of cyber security and data transfer efficiency. In remote areas like polar regions, satellite coverage is insufficient, congested or non-existing. The cost of satellite communication is also considered quite high. Some vessels also have on-board sensors that automatically send data e.g. from the engines to equipment manufacturer or to the shipping company on shore.

[42] Norwegian Coastal Administration. Accessed 04/09/2019

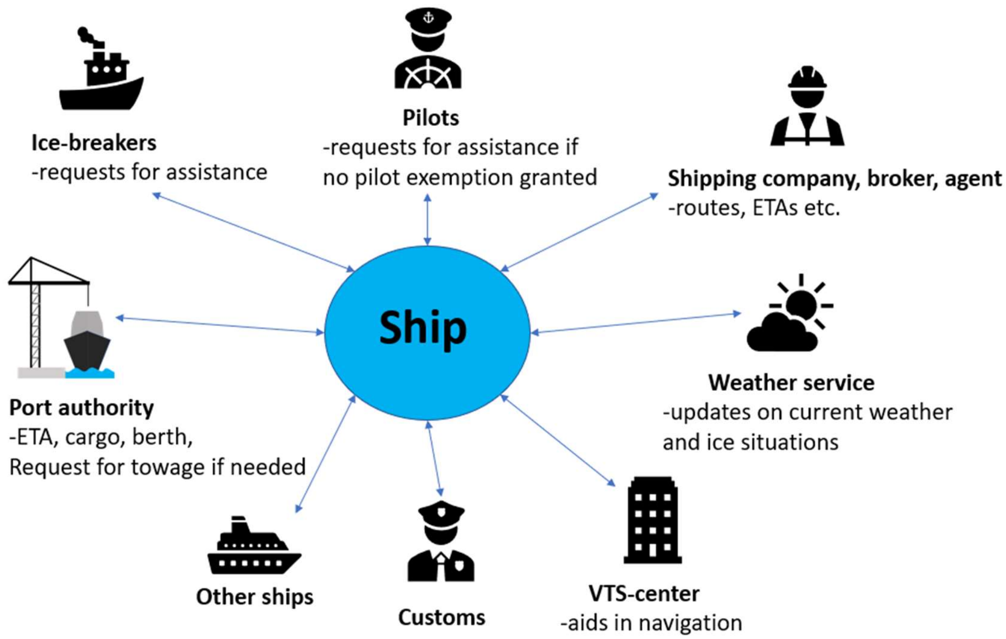

Figure 2. An example of the exchange of information by the ship while sailing. A major part of the communication is done via VHF radio and satellite. ETA= estimated time of arrival.

3.3 Freight contracts

The main types of cargo shipping operations are *liner traffic* and *tramp traffic*. In regular liner traffic, the vessels travel on predetermined routes with set port calls and timetables. Especially on longer lines, the schedules are often indicative, such as "departures every two weeks". The route may include several loading and discharging ports, which are not all visited on each trip.

Tramp traffic, also known as *spot traffic*, means transport of cargo between occasional ports without a regular timetable. Freight is usually freely determined by supply and demand and the transportation is done according to the terms of the charter agreement. Ca. 3/4 of global trade is tramp traffic and 1/4 is liner traffic. Tramp traffic is further divided in time charter, voyage charter and demise charter traffic.[43]

Voyage charter traffic is the most common type of tramp chartering. The shipper of goods buys transport for a single voyage from the operator at a fixed price from port A to port B[44]. The shipping company transports the agreed cargo from the loading port to the destination[43]. In time charter traffic, the shipping company charters the vessel to a charterer for an agreed time period and fee. The shipowner is responsible for the crew costs, capital costs and the maintenance of the vessel. The charterer takes care of the operating costs such as fuel and port fees. In demise or bareboat chartering, the shipowner provides only the ship to the charterer and pays for all operating costs including fuel, crew, port fees and insurances.

In the Contract of Affreightment (COA)[45], a shipowner or operator agrees to transport a given quantity over a fixed time. Unlike other chartering types described above, no specific ship is named in the contract. It is up to the shipowner or operator to provide ships as needed for the project. The cargo owner is liable for payment whether the cargo is ready for shipment or not.

There are identified bottlenecks in the freight contract system for implementing optimization and emission reduction measures. The charter party is a contract to lease or hire a vessel applied in tramp traffic between the shipowner and the charterer. The charter party is issued

[43] Tapaninen, U. 2019. Merenkulun logistiikka. Otatieto
[44] Grammenos, C. (Ed.) 2010. The handbook of maritime economics and business. Taylor & Francis
[45] Stopford, M. 2009. Maritime Economics. Routledge. 3rd ed.

prior to loading and includes information of the vessel, the carried cargo and the consignments related to the handling of the cargo. It defines the rights and responsibilities of the two parties which they can in principal agree upon as they wish, but it is commonly based on a standard form. Because the shipping industry operates in a global market, the contracts applied are of international character. BIMCO is an international shipping association aiming to assist its members by facilitating commercial operations by e.g. developing standard contracts and clauses.[46] Due to the traditional nature of shipping, the widely known standard contracts and clauses are used rather than negotiating changes. Moreover, the negotiations are often conducted in a limited amount of time and under high economic pressure.

As the charter party stipulates where and when the cargo must be transported, the shipping companies normally profit from arriving in a port as early as possible. The vessels must follow the laycan[47] stated in the charter party. The time period reserved for loading and unloading cargo is called laytime. If the agreed laytime is exceeded, the charterer might need to pay a demurrage fee for the over time. Laytime starts after a Notification of Readiness (NOR) is given by the ship master.[48] This leads to a situation where vessels have economic incentive for rush-to-wait to ports.

Terms of delivery are voluntary rules of conduct between the buyer and the seller that are meant to ease the trade between parties. The newest version of Incoterms 2010 is a set of pre-defined, most commonly used delivery terms maintained by the International Chamber of Commerce (ICC)[49]. The terms are primarily intended to communicate the tasks, costs and risks associated with the transportation and delivery of goods and are a registered trademark of the ICC. Figure 3 explains the differences between the terms.

[46] BIMCO. Accessed 01/08/2019
[47] Period of time during which the shipowner must give the notice of readiness to the charterer that the ship has arrived and is ready to load
[48] Personal communication, T. Fröjdman, Bachelor of Maritime Management, 01/08/2019
[49] International chamber of commerce. Incoterms 2010 rules. Accessed 28/08/2019

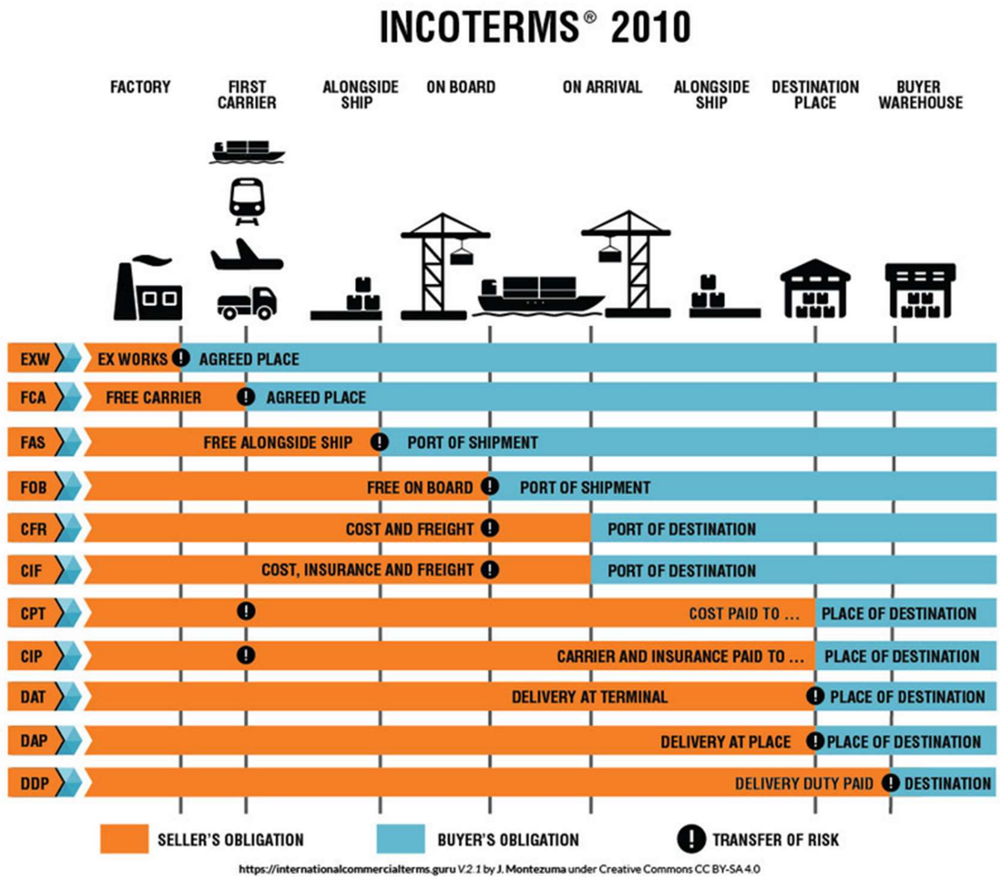

Figure 3. Incoterms 2010 as illustrated. The terms define the party responsible of the cargo during the transportation, the party that pays the expenses and the responsibilities of the buyer and the seller. Source: https://internationalcommercialterms.guru/ Accessed 17/07/2019. Picture in courtesy of J. Montezuma under Creative Commons CC BY-SA 4.0

Some of the most common Incoterms in use are[50]:

- **DDP** (Delivery Duty Paid). The seller pays the expenses, including import duties and taxes in bringing the goods to destination, and is responsible for delivering the goods to the country of the buyer. The seller is responsible for the goods clearance though the customs in the country of the buyer.
- **EXW** (Ex-Works). The seller delivers when placing the goods at the disposal of the buyer available at its' premises or another place. The EXW has the minimum obligation to the seller and that the buyer bears the risks of bringing the goods to the destination.
- **DAP** (Delivery at Place). The seller delivers when goods are placed at the disposal of the buyer on the arriving means of transport ready for unloading at the named place of destination. The seller bears the risks in bringing goods to the place of delivery. The seller also takes care of legal formalities in the exporting country and clears the goods at his own risk but in the country of destination the customs clearance is done by the buyer.
- **DDP** (Delivery Duty Paid). The seller is the party responsible for the delivery of goods to named place in the country of buyer. The DDP places maximum obligations to the seller and minimum for the buyer as the seller bears all costs and risks in bringing the goods to destination such as import duties and taxes.
- **FOB** (Free on Board). The seller delivers the goods on board the vessel designated by the buyer and therefore bears costs and risk to the point that goods are on board the

[50] O'Connor, E. (Ed.) 2013. Incoterms 2010 Questions and expert ICC guidance on the Incoterms 2010 rules. International chamber of commerce, publication No. 744E.

vessel. After the goods have been loaded, the buyer bears the risk. The term is used only in waterborne transports.

Freight rates are based and determined on negotiations between shipping companies and forwarding agents or cargo owners. In liner traffic, the tariffs and contracts are predefined and exact between ports and different cargoes. In voyage charter traffic, the cost of cargo is defined by the voyage and can be agreed between the shipping company and the cargo sender. The shipping related costs are dependent on the type of freight contract. Figure 4 shows the responsibilities of a shipowner and a charterer in different types of contracts. It shows also who is responsible for fuel oil costs, which are a part of voyage costs, and whose interest is to reduce that cost. Most of the fuel and thereby emission savings could be accomplished during voyage and cargo handling.

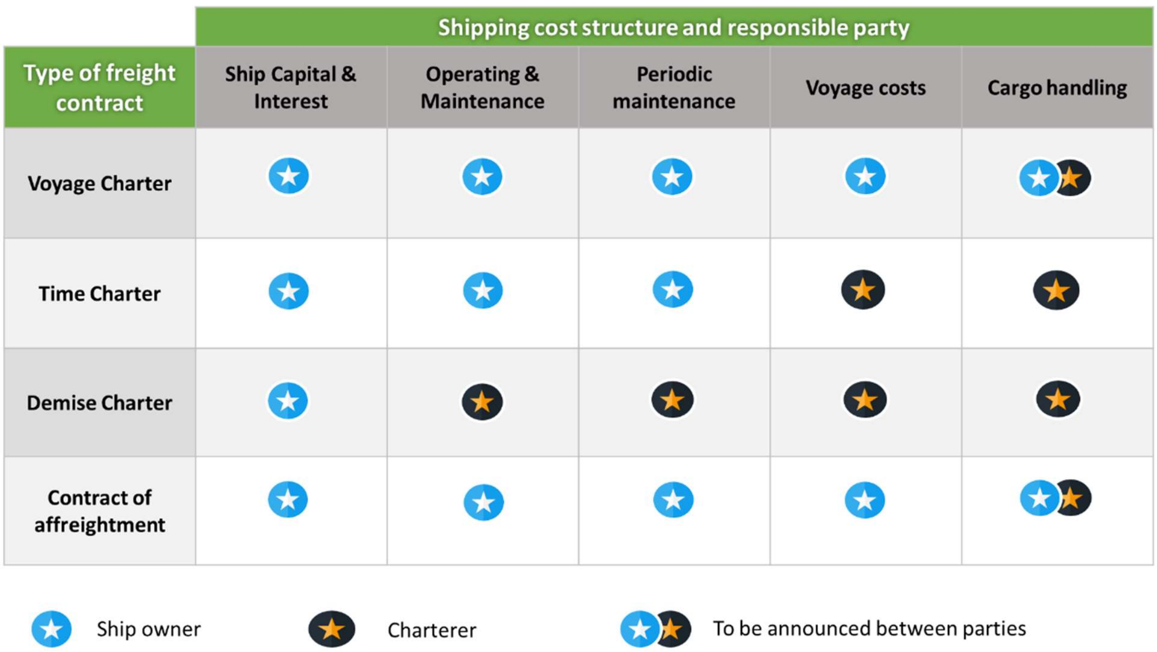

Figure 4. The division of costs in different types of charter contracts, compiled by the authors. Whoever is responsible for voyage costs, has the economic incentive for reducing fuel consumption and thereby emissions.

The fuel costs make up the major share of the operating costs of a ship (Figure 5). Therefore, cutting down fuel consumption will also cut down the total cost of a shipping operation, as well as emissions.

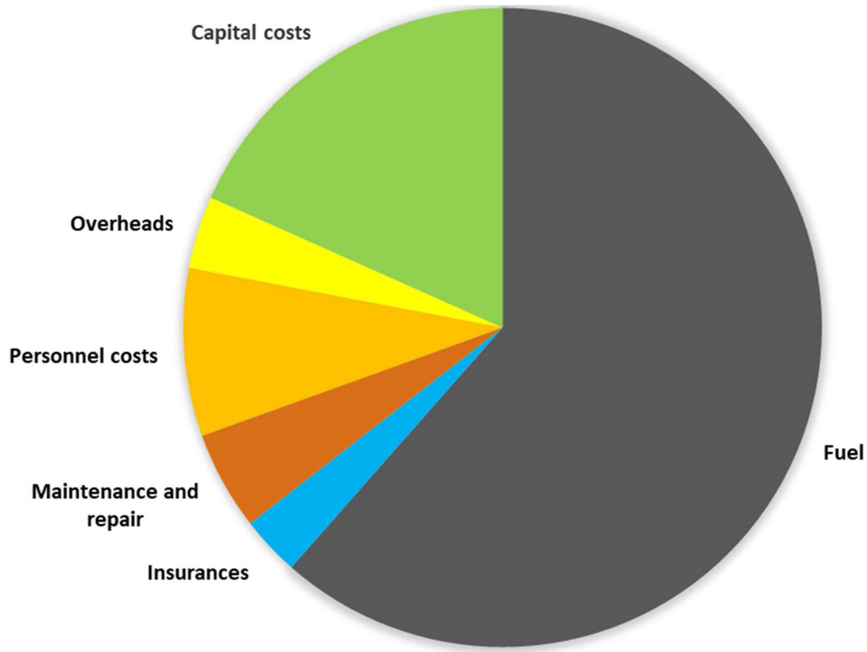

Figure 5. The typical ship operating cost distribution for the Finnish flagged fleet operating mainly in the North European SECA (Sulphur Emission Control Area). Applied after Karvonen & Lappalainen 2014.[51]

3.4 Optimization measures for emission reduction

3.4.1 Just-In-Time arrival

Ships seems to sail faster than needed and "rush-to-wait" to ports. This is a result of at least two reasons; "first come first served-policy" in ports and the current economic structure of freight agreements. A dry or general cargo vessel in the Baltic Sea may wait outside the port for 40 hours of its 110 hours long voyage before given a permission to enter the port[6]. Globally, a ship might spend on an average 5-10 % of one voyage waiting at an anchorage outside a port[52]. Sometimes also the opposite problem arises e.g. with bulkers arriving to the port later than scheduled[53].

The gains from a more accurate calculation of the estimated time of arrival are significant in terms of efficiency. It enables adjusting engine settings for fuel efficiency and saving fuel at optimal speeds, thereby reducing GHG emissions but still knowing that the destination will be reached at the given time. Having an accurate arrival time also enables ports to handle incoming ships more efficiently.[32]

Implementing "Just-In-Time" (JIT) operations would cut the time ships spend idling outside ports as well as help ports to make more optimal use of their capacity and to achieve shorter transit times. JIT is enabled by e.g. AIS and AI technology where a computer programme calculates the optimal sailing speed based on previous sailing and weather data etc. There are

[51] Karvonen, T. & Lappalainen, A. 2014. Alusliikenteen yksikkökustannukset 2013. Liikennevirasto, suunnitteluosasto. Helsinki 2014. Liikenneviraston tutkimuksia ja selvityksiä 41/2014. ISSN-L 1798-6656
[52] Lloyds' List 2019. 'Smarter' ports can help cut emissions.
[53] Full Avante News, Maritime Affairs 2018. Lars Jensen, "Pacific Reliability Collapses" Accessed 11/07/2019

several studies and calculations on how much JIT-shipping could lower the GHG emissions from shipping, varying from few percentages to even a third of the total emissions[6 54 55].

In contrast to JIT arrival or ecospeeding, the reduced waiting time in ports does not extend transportation times. They just minimize time at anchorage, and therefore allow for lower optimal voyage speeds. Poulsen & Sampson (2019)[56] list several recent studies showing that reducing waiting time in anchorage and in ports is a cost-effective energy efficiency measure.

There are, however, several challenges with implementing JIT still today. For example, for bulk carriers and tankers, the clauses in charter party contracts act as a barrier to the uptake of JIT. Issues such as the reliability of departure times are being discussed so that the operations would be smarter and more efficient in the future.[57]

3.4.2 Virtual arrival

Virtual arrival is a method for ensuring JIT arrivals in shipping. Recently, some charterers and shipping companies have tried to implement JIT arrivals by introducing "virtual arrival clause" in freight contracts. It means that if e.g. the receiving terminal cannot accommodate the vessel at the originally expected time, the clause enables the vessel to slow down and postpone its arrival to the terminal. With the virtual arrival clause in the agreement, the vessel is deemed to have arrived "virtually" at the originally agreed time.[56] With this clause, the "rushing-to-wait" practice could be avoided and sailing speed reduced. The related bunker saving can be then divided between the charterer and shipowner. BIMCO has developed virtual arrival and slow-steaming clauses which shipowners and charterers could include in their agreements to allow for speed optimization during voyage[58]. Speed optimization can be defined as the selection of an appropriate speed profile for the ship so as to optimize a specific objective, such as fuel consumption.

Virtual arrival has identified as an efficient way to divide the benefits from JIT arrival and optimal sailing and many studies therefore expect it to be one of the efficient ways to emission cut downs. However, the virtual arrival clause has so far been used in very few charter parties, due to several reasons[56]. Cargo owners have commercial imperatives other than fuel savings which outweigh the benefits from virtual arrival. Many types of cargo have significant price volatility which means that the value of the cargo may increase with waiting. The value of the cargo in many cases exceeds the cost of freight and fuel by many magnitudes. This means that the fuel savings and slow-steaming due to virtual arrival does not appeal to many charterers, who are more focused on ensuring immediate access to highly valuable cargoes. Waiting time might in fact have commercial imperatives for cargo owners. Also, financial risks related to potential delays resulting from unforeseen events make charterers reluctant to slow down the voyage too much. Charterers might be more concerned about certainty for delivery of a highly valuable cargo than any possible fuel savings from virtual arrival. There might also be logistical challenges in ports and terminals, e.g. berths might be occupied by other delayed vessels. Also, in many ports a ship might need to rush for not "losing its ticket in the waiting line for berth" despite virtual arrival. For these reasons, shipping is unlikely to achieve significant GHG reductions via virtual arrival.[56]

3.4.3 Voyage and route optimizing

Voyage optimization processes aim to improve the operational efficiency of a ship by optimizing route and speed profiles and consequently bring economic benefit to the shipping stakeholders. There are different strategies to the optimization such as finding the shortest

[54] Port of Rotterdam 2019. Move forward: step by step towards a digital port. White Paper.
[55] Johnson, H. & Styhre, L. 2015. Increased energy efficiency in short sea shipping through decreased time in port Transportation Research Part A: Policy and Practice. 71: 167-178
[56] Poulsen, R. & Sampson, H. 2019. Swinging on the anchor: The difficulties in achieving greenhouse gas abatement in shipping via virtual arrival. Transportation research Part D 73: 230-244
[57] Marine Traffic Blog 2019. Pushing ahead with Just-In-Time shipping. Accessed 26/07/2019
[58] Interview of Lars Robert Pedersen, BIMCO, 08/08/2019

route, avoiding bad weather and utilizing strong ocean currents to reduce fuel consumption and emissions.[59] Weather conditions for ships can in general be described in terms of wave height, wave direction, wave frequency, wind speed and wind direction, of which dominant wave height, dominant wave direction and dominant wave frequency have the largest impact on travel time, fuel consumption and safety. Most existing voyage optimization tools optimize with respect to one criterion at a time, treating other relevant criteria as constraints. Recently, also multi-objective optimization tools for optimization of ship routes have been developed.[60] [61]. Most currently available route optimization services provide the optimized routes for the ships' Electronic Chart Display and Information System (ECDIS)[32].

The combined effects of weather impact vessel performance in a proportion of 80 %, while other factors only count for the remaining 20 %. Modern forecasting methods and data allow ship masters to identify levels of resistance as a result of weather factors and optimize their routes to avoid adverse conditions. Moreover, extreme weather is happening more often due to the global climate change. The best option would be to use weather and ship data from past voyages to identify how ships will perform in a variety of weather conditions. Machine learning could be used to build predictive models for weather forecasting.[62]

Voyage Management (VM) is a larger concept, concerning strategic, tactical and operational decisions about a voyage, such as planned and executed routes of a certain ship and its interaction with nearby ships in each position. It focuses on the initial planning phase of any sea voyage and the ability to monitor the execution of that plan. VM supports improved route planning, route exchange, and route optimization before and during the maritime voyage. Especially in this phase, VM connects ships, adds intelligent processes and new tools to enable all stakeholders to increase their situational awareness during the voyage, providing faster, more secure and transparent information exchange.[32]

Variations in vessels' speed represent one of the clearest symptoms of inefficiency in shipping, i.e. ships are not navigating at their most efficient speed most of their time. The reasons underlying these speed distributions vary. These include aspects that are inherent to the routes covered by the ships, e.g., calm waters or complicated geography, to unexpected changes in berth availability in the destination ports, circumvention of congestion or meteorological difficulties/events during navigation. Better synchronization with ports, between ships, or using weather forecasting services and route optimization made available to ships, would largely reduce speed variations. The potential savings are related to bunker consumption and, hence, bunker costs for the route sailed. Optimizing the route has a strong impact on the operational costs for fuel and it is translated into GHG emission savings.[32]

3.5 Digitalization as an emission abatement method

Based on the interviews, technology providers, shipowners and shipping organizations as well as authorities and academia saw that digitalization will have a high importance on the reduction of GHG emissions (Figure 6). Cargo owners, agents and port operators believed that digitalization will have a smaller role on emission reduction. The differences in the answers are partly explained by how the interviewed parties understand digitalization. The ones who saw digitalization as a major tool in reaching GHG reduction goals, often spoke about data- and platform-based business models and how they could transform the whole industry. The ones who saw less potential for GHG emission reductions through digitalization, often referred to digitalization as a helpful tool.

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[59] Ahokas M. 2019. Analysis of voyage optimization benefits for different shipping stakeholders. MSc thesis. Aalto University. 83 pp. + app.
[60] Andersson, A. 2015. Multi-objective optimization of ship routes. MSc thesis. Chalmers University of Technology. 27 pp.
[61] Vettor, R. & Guedes Soares, C. 2016: Analysis of the sensitivity of a multi-objective genetic algorithm for route optimization to different settings. Maritime Technology and Engineering 3. Proceedings of MARTECH 2016.
[62] Ship Technology 2018. The 80/20 rule: optimizing voyages to improve vessel performance. Accessed 09/09/2019

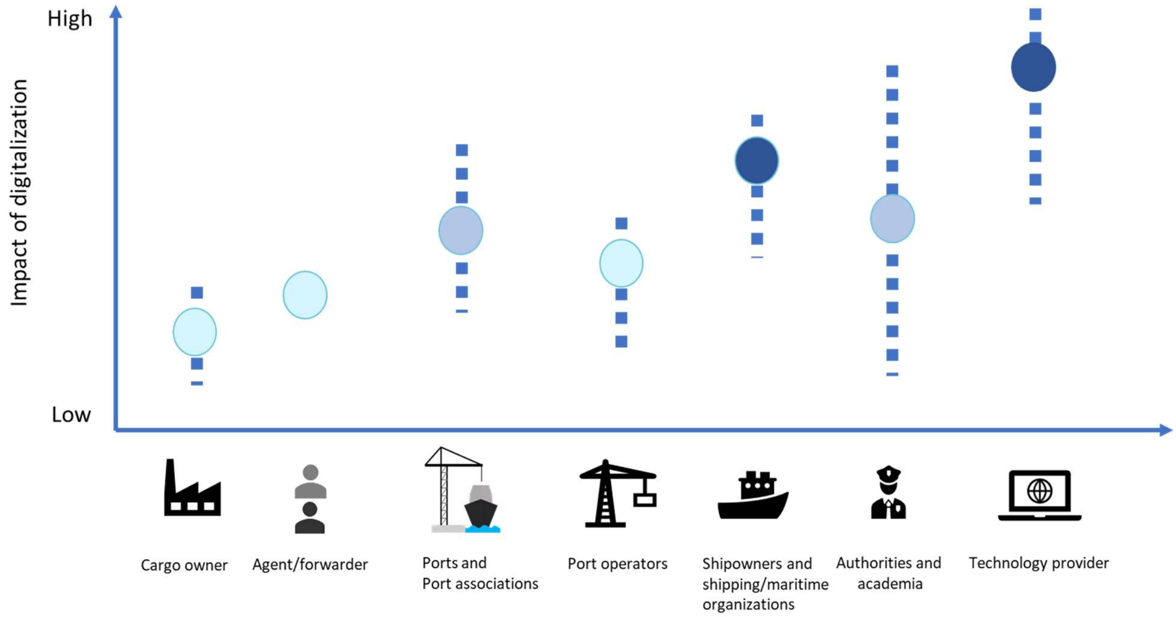

Figure 6. Views on effectiveness of digitalization in emission abatement according to the interviewed parties, n=23. The answers were interpreted by the authors on a free scale from low to high impact. The lighter the point, the less answers. The range of the answers is represented as a dashed line.

Interviewees who saw digitalization to have an important role (**high impact**) in reaching GHG emission reductions pointed out e.g. the following:

- Measures that can genuinely reduce the use of energy is maritime industry are all related to the use of data and data-based operations. Abatement measures that don't require any kind of digitalization are quite scarce.
- Major drop-down in the emission levels will happen when the whole maritime transport system and related business models will change due to digital disruption and data- and platform-based services.
- Digital disruption (platform-based business models) will probably take place earlier than large scale use of autonomous ships, technical disruption in energy efficiency or exploitation of new energy sources.
- New business models based on data and digital solutions can significantly influence emissions through optimization.

Those among interviewees who found digitalization to have a smaller role (**low impact**) in reaching GHG emission reductions pointed out inter alia:

- Digitalization can help in emission reduction, but it will not make or break the IMO 2050 goals because their impact is minor compared with other measures.
- Digitalization and optimization can slow down the growth of emissions, but if shipping continues to grow, the benefits will stay moderate.
- As long as shipping is based on fossil fuels, emission reductions will be small.
- Gaining real-time and accurate information on specific emission sources onboard vessels and what influences them means that emission cut-down measures can be targeted better.
- Digitalization is one part of the solution, but more incentives are needed to get the industry to implement and use the optimization tools.

A SWOT analysis based on the interviews is presented in

Table *2.*

Table 2. A SWOT analysis of digitalization as a GHG emission abatement measure according to the interviews.

Strengths	**Weaknesses**
• Enables data-based optimization of vessels' energy efficiency, routes and voyages, port calls, loading and unloading and hinterland transports • Optimization of information exchange and digital document flow • Speeds-up cargo handling processes, releases resources to other tasks • Data and systems exist or are possible to create and implement • Enables automation of port and ship operations • Platform-based possibilities for data sharing enable better optimization of cargo flows and vessel voyages	• Limited data sharing capacity through satellite connections • Lack of willingness to share especially real-time data • First-in, first-served principle in ports demines optimization possibilities • Current cyber security risks, use of same data connections for many types of data • Lack of know-how to fully implement the benefits • Revenue logics: fuel savings are not big enough incentives for charterers or shipowners • Difficult to optimize the whole transportation chain; partly optimizing is not a good solution • Number of small actors with limited resources • Several competing systems and data formats • Fragmentation of available data • Incompatibility of authority systems • Varying data quality • Overlapping systems and standards
Opportunities	**Threats**
• Major emission reduction through optimization of operations (routing, JIT, port calls, port operations, connection with land transportation, cargo intake optimization, fleet optimization etc.) • Digital disruption of cargo market into real-time data-based platform: better optimization of the whole supply chain and its energy consumption • Better data access opens possibilities for new businesses (also for emission abatement solutions) • Saving energy and optimizing the use of assets can also create economic benefits	• Industry is not willing to change currently used traditional freight contract models and traditional ways of operating • Ownership of data as a business asset, holding-on to data • Disruption from outside actors, loss of business for current industry actors • Global industry with enormous amount of different operational models, difficult to streamline • Competition within industry • Low willingness to invest in new technologies, not enough market drivers • Cyber security threats • Business risks related to data opening • Slow administrative processes vs. rapidly developing and changing technologies and innovations

3.6 Identified challenges in implementing digitalization

One of the aims of the study was to identify the main challenges the industry is facing regarding digitalization as an emission abatement tool. The same challenges were brought up in most of the interviews (Table 3).

Table 3. The main identified challenges hindering digitalization in shipping, based on interviews.

Identified challenges	Main reasons	Related problems
Fragmented industry and disconnected supply chain	• High number of actors and fragmented responsibilities	• Information friction • Optimizing only parts of the chain creates problems elsewhere and is not efficient in terms of the whole chain • Great variation in port operation models
Traditional, rigid and global industry	• Long history, traditional ways of working • Long contractual relationships • Lack of understanding of the global nature of shipping in national level • Global giants in the markets	• Varying national regulations • Global giants have a lot of power
Freight contract models and revenue generation	• Very old freight contract models • Risk management with established contract models • Role of the charterer dominant in the charter party	• Revenue logic based on "time is money", no incentive for fuel savings • Restricted possibility to take onboard "part cargo" in addition to agreed cargo
Established procedures and operational models	• "First-in, first-served" principle in ports, based on freight contracts and operation models • Practices, work shifts • Ownership structures and division of responsibilities in ports • Organizational boundaries, silos	• Vessels rush to wait in port • Operational hours in ports limit the loading and unloading efficiency • Rigid ownership of data • Lack of trust
Lack of investments in digitalization and other emission reduction measures	• Low willingness to invest due to competition and low profit margins • Possible uneven division of benefits from investments • Lack of market pressure to invest in new technologies • Forerunner risk • Long lifespan of vessels	• Slows down the development of digitalization and emission reductions
Fear of disruption and guarding of the status quo	• Data based business models might change the current revenue logic • Companies reluctant to disrupt their own business	• Holding on to one's own data • Low willingness to discuss the meaning of digitalization and possible disruption among the industry • Fear of outside disruption
Lack of know-how and technical obstacles	• Lack of IT know-how inside industry • Lack of shipping know-how in IT industry • Many digital technology providers former vessel equipment manufacturers	• Unsuitable digital solutions for shipping • Underutilised data

Limited communication means and data transfer capacity	• Limited data transfer capacity between vessel and shore • Unreliable and expensive satellite connections	• Insufficient data flow between vessels and shore
Challenges with information security	• Lack of safe data transfer capacity between vessel and shore • Wide utilisation of e-mails for data sharing • GDPR	• Information security issues related to critical data
Lack of data and information sharing	• Lack of real-time data • Lack of publishing of exiting data • Lack of data sharing between parties, partly due to current patterns of ownership • Varying quality of existing data	• Optimizing operations and energy efficiency not possible without exact and real-time data available for different parties • Business risks related to opening one's data
Lack of standards and standardized systems	• Overlapping and unconnected systems in different ports and between authorities • Lack of single windows • Current information systems don't interact; insufficient APIs	• Lack of standard or fluent way of information sharing creates obstacles for optimization • Contradictory views on the need of standardization / regulation • Overlapping standardization initiatives

Gustafsson et al. (2019)[6] identified five different problem areas hindering emission reduction in shipping. These were 1) non-optimal speed profiles, 2) low ship utilization rates, 3) time spent in ports, 4) lack of incentives for offering environmentally friendly freights and 5), lack of investments in new vessels and better technology. Traditional working culture, lack of interoperability of data sources and challenges in security legislation are also identified as major challenges in the digitalization processes in ports[41].

3.6.1 *Fragmented industry and disconnected supply chain*

One of the major challenges in introducing digital tools and operation models and getting different actors to use them is that the maritime industry is very fragmented with high number of actors and companies. Maritime logistics was recognised by the interviewees as an isolated industry rather than a genuinely connected part of the supply chain.

Interviewees pointed out that the high number of actors in the industry restricts and delays the information flow. Information is shared slowly, through different and partly overlapping channels and through intermediate parties such as agents. A lot of information friction exists both inside and between organizations. As an example, there might be several different companies involved in a single port call of one vessel – piloting company, port authority, port operator, land transportation company - that all need to communicate together in order to get vessel berthed and unloaded. Large amount of different size companies in the industry also means that parties have different resources for optimization and digitalization. Small actors usually manage small amounts of data and are not yet digitalized in the same way as bigger players.

Different segments of shipping have different possibilities to implement digitalization and optimization. E.g. in the container segment, there are no huge issues and the actors have already made improvements, like collaboration in digital initiatives and common standards of the container lines alliance[23]. In container lines, charterers are interested in improving their environmental performance and reducing their carbon footprint. On the other hand, in the dry bulk segment, there are a lot of voyage chartering contracts where the shipowner pays the fuel costs and needs to transport goods straight from A to B without a possibility to optimize and reduce emissions. In the tanker segment, there is often a need for a ship to be in time and therefore ships are requested to arrive early and wait in anchorage rather than to be late and cause huge costs for the charterer.

As the supply chain consists of multiple parts and actors, optimizing operations today often involves only a part of the chain. This partly optimizing is one the problems hindering real emission reductions. Optimizing one part of the logistical chain easily creates problems elsewhere, e.g. reducing speed at sea means that there is a need for increased speed elsewhere. For the emission point of view, it is a zero-sum game and therefore optimization efforts should always look at the whole supply chain. This in turn is extremely difficult due to the fragmented nature of the industry.

One of the challenges mentioned is the large amount of ports and their different ways of operation. On one hand, there are highly automated large ports with a lot of information available, and on the other hand, very small and still very manually operated ports. The challenge is that a vessel needs to be able to optimize its voyage and port calls in each of these. The fragmented nature of the port sector is further complicated by the fact that there is no global regulatory body for ports in a way there is for shipping (i.e. the IMO). This means that it is extremely challenging to get ports globally involved in common digitalization and emission reduction efforts.

There is also considerable potential for improvements in collaboration and flexibility within the logistics chain, a need to improve understanding of the challenges, and a need to build trust between different actors.

3.6.2 Traditional, rigid and global industry

Shipping is a very traditional and rigid industry and, in many cases, based on long contractual relationships. Personal skills and know-how of the stakeholders are as crucial and therefore not easily replaceable by automated data-based analytics and algorithms.

It was stated by many of the interviewees that due to the traditional nature of shipping, changes have always been slow. The land side of the logistical chain already has systems and platforms in place, and the maritime side is lagging far behind. This is a challenge also since in order to optimize the whole supply chain and thereby cut down emissions in shipping, solutions for the whole chain should be found.

Also, the global nature of the industry creates challenges for information sharing and optimization. Often the global industry is faced with varying national regulations. Lack of understanding on national level of the complexity of the shipping industry and its global nature was mentioned in several interviews.

The global playfield has also created so-called global giants into the industry. According to some of the interviewees, it is unrealistic to expect that these giants would adapt their ways of communication according to the varying requirements of single ports and small port operators. These global giants also have a lot of power by controlling a huge amount of data and not being very keen to open it to the rest of the industry.

3.6.3 Freight contract models and revenue logics

Established agreement formats between charterer and shipping company are one the frequently mentioned challenges when talking about the optimization of energy consumption and port calls. A lot of unnecessary waiting and low utilisation of transport capacity are currently wasting energy and creating unnecessary emissions. Charter don’t necessarily create any incentives for fuel savings. It was stated in the interviews that the established freight contract models date back to the sailing-ship era and fit quite poorly to today’s shipping. It was also pointed out that the current contract models are not directly in conflict with low carbon targets of the industry, but they cause challenges.

Although there is legally nothing hindering the contracting parties from making new kind of contracts that would better enable e.g. JIT or port call optimization, this is not done very often. The contract formats in use reflect the fact that transporting the valuable cargo where and when it needs to be is of more economic value than possible fuels savings achieved by route or speed optimization. Use of established contract models is also a risk management method. Legal claims and disputes are quite common in shipping and the role of solid, commonly used contracts is to avoid these.

The role of charterer is dominating in the charter party and the ship's captain cannot solely decide a speed the vessel can sail. The vessels must follow the laycan, i.e. the time period it needs to be in the port[47], stated in the charter party. Many of the contract models also hinder the taking of "part cargo", meaning that even if the vessel would have room for some other cargo during the same voyage, it cannot take it due to contractual matters.

3.6.4 Established procedures and operation models

There was a lot discussion about excessive waiting time in ports with the interviewees. One of the major challenges are related to established procedures and operation models. The "First in, first served" principle in ports was mentioned several times because in most of the ports, you cannot reserve a berth at a certain time, but the berths are divided according to the arriving order. Therefore, vessels rush to ports, often only to wait to be served. This "Race to get there first" creates unnecessary emissions via unnecessary high speeds at sea and possibly long waiting time before berthing. Better collection and sharing of port and ship data and therefore enabling better voyage optimization is a crucial tool in tackling this. However, this challenge is firmly bound to freight contract models and is therefore not only corrected by better data access. The same race applies also to the main shipping routes like the Panama and Suez canals.

Another operation model that was to hinder emission cut downs was the operation schedules at ports. There are not many ports that operate 24 h, 7 days a week, and this naturally creates idle time for vessels. Also, the practices related to operation shifts might create rushing to ports. It was mentioned that with some port operators, the loading and unloading is not started in the middle of a work shift, and therefore vessels speed up to get to the port before the start of the shift.

The varying division of responsibilities and ownership structures in ports was pointed out to hinder port call optimization. The way different ports are organized makes data sharing difficult since data ownership and responsibilities are organized very differently in each port. Ownership of data was stated to be a problem since the industry is still set in silos, and strong competition and even prejudices between different actors still exists. Lack of trust between e.g. shipping companies and ports was also mentioned.

3.6.5 Lack of investments

Lack of investment capacity and low willingness to invest slow down both digitalization and other emission reduction measures in the maritime supply chain. This is strongly linked to the cost structures and revenue creation models of the industry. The current economic situation in the shipping market has brought profit margins down and most of the shipping companies are very small. Profit margins are also down because there are too many parties in the logistic chains each taking their own margins. Therefore, they lack the possibility to invest in emission abatement technologies and to modify business models or ways of operations based on new digital solutions. This is a global challenge, escalating especially in small markets with more stringent environmental regulation, such as in the Baltic Sea / North European SECA area.

There was a strong dispute between interviewees on whether the needed investments in digital solutions are high or moderate. An issue stated to lower the willingness to invest was that the benefits are not necessarily directly realized to the investor. Some of the digital solutions benefit the whole industry, not just the investing party. It was stated that no investments are made unless their payback time is short, and this is not necessarily the case with new digital systems. Some interviewees saw that if no regulations require data sharing or data-based optimizations, the level of investments needed to reach the emission reduction goals will lack behind. Even though there is common understanding that emission reductions are needed, it all comes down to what it costs. In order to protect oneself from the fierce competition, it is not wise to deliberately raise one's own cost level. If the final customer is not willing to pay more to lower the emissions from transportation, the willingness of one actor to invest in emission abatements stays low. There is a lack of market pressure that would serve as a pushing factor in implementing new technologies. Also, continuous tightening of maritime regulation and its economic burden is hindering the development of digital tools. Companies must focus major efforts to follow the tightening legislation, and there is not much left for innovations.

A forerunner risk is also combined with investing into new systems. Being the first to implement something new always comes with risks and creates free experiences for the competitors to utilize afterwards. Also, the long lifespan of vessels was brought up when discussing investments.

3.6.6 Fear of disruption and guarding the status quo

There is a strong guarding of status quo in the industry. New, more data-based business models might change the current roles, processes and division of labour. The solutions which will generate most of the emission savings and economic benefits were considered possibly to disrupt the industry most by changing the revenue generation models. This kind of disruption is not only considered as a positive thing by individual actors. Because companies are reluctant to disrupt their own business, they are holding down to one's own data and are sometimes reluctant to share it. It is very sensitive to bring about new solutions, since you must make sure you don't step into existing actors' territories.

Due to these reasons, connecting the industry to discuss the possibilities of digitalization is a major challenge. It was argued that the industry is currently talking about the wrong thing. Instead of the current discussion on individual energy optimization technologies, understanding on the future maritime traffic system would be crucial. The interviewees pointed out that there is a lack of recognition of this issue. There is no common understanding about the future of maritime industry regarding GHG emission and digitalization. Everyone is approaching digitalization from their own angle and how they as a company could benefit from it instead of how the industry needs to be transformed by digitalization. The paradox is that although many mentioned that possible digital disruption will benefit the whole industry, it will not necessarily benefit single companies.

Concerns regarding external actors were also brought up. If the shipping industry itself does not take proactive action on digitalization, the disruption was expected to be introduced by external actors, e.g. platform operators such as Amazon. The industry was considered to have been so far protected from disruption by its fragmented and capital-intensive nature.

3.6.7 Lack of know-how and technical obstacles

There are also several technical and know-how related issues that hinder the development of digital systems and data-based optimization in the industry. Some of the technology providers pointed out that the level of digitalization in maritime industry is not on the level the marketing talks of different companies might suggest. There are still major lacks in basic information connections and data collecting.

The information flow from ship to shore and vice versa is one of the challenges. Regarding data connections, vessels are still more or less disconnected islands and not a real-time part of information networks. Vessels rely mostly satellite connections that are expensive and sometimes unreliable. The data transfer capacity is quite limited, partly due to the pricing models. The limited data transfer capacity in vessels need to be prioritized and it is therefore mostly used for the most critical business data, which means that there might not be capacity left for collecting continuous data for optimization purposes.

Lack of know-how both outside and inside the maritime industry were recognised to hinder the development of digitally based solutions. When developing digital solutions for shipping, know-how of the industry and its practices is crucial. This is still not well understood by information technology companies outside the shipping industry. For example, the reality of limited technical data sharing possibilities onboard vessels was not understood, and the proposed solutions were of no use in shipping, although working well on land.

Also, a major lack of digitalization know-how inside the industry was recognised by the interviewed parties. Although technology to process data would already exist, the know-how does not. Companies do not know how to utilise the extensive amounts of data for actual optimization. It was also pointed out that most maritime digital solution providers are originally vessel equipment manufacturers, whose focus on digitalization might differ from platform-based models that are spreading fast in other sectors. This know-how bottleneck has also been recognised by the Finnish Government, which stated that the increase of information will lead to an increased demand of experts in the field of data analytics[12]. The shortage of know-how may lead to development bottlenecks in many companies.

3.6.8 Challenges with information security

The insufficient level of information security was one of the technical challenges related to ship-shore, shore-ship and ship-ship connections. For example, the vessel’s critical business data is shared along same connection as the entertainment use of the crew, which brings about security risks. The information sharing in the industry still relies a lot on emails, which is far from a secure or efficient mode of communication. However, it was also noticed that cyber threats might cause some challenges when more and more digital systems and services are in use.

EU’s General Data Protection Regulation (GDPR)[63] was also mentioned by the interviewed parties as one of a problem. The GDPR has brought up new challenges in sharing of information.

3.6.9 Lack of data and information sharing

There is still a lack of available data for optimizing. For example, vessels’ expected arrival times to ports are not publicly available. In order to optimize ship operations this would be crucial information for shipping companies. Shipping companies might not even know beforehand what kind of scheduling systems the port they are calling have.

Need for real-time data was stated by most of the interviewees regardless of their position in the transportation chain. Quite a lot of data exist but it is published as static, one a week or once a year data, which is not helpful for optimizing real-time operations. Unless you can see for example the cargo flows real-time, you cannot optimize them and therefore the operations are easily wrongly resourced. Especially the lack the real-time data of vessel arrivals and cargo flows from ports was stated as major hinders of JIT operations. Now it is e.g. up to the agent’s activity how much information on port circumstances the vessel gets beforehand.

Varying data quality and its scattered locations are also obstacles in the optimal utilization of data. Some of the interviewees stressed out that in case the whole supply chain data is not possibility to bring together, there is no change to optimize the usage of the whole chain.

Lack of data sharing was mentioned as a major hinder for data-based optimization efforts. In cargo business the lack of transparency was pointed out to block the possibilities for optimization. Some of the interviewees described so-called data sharing “deadlocks” that exist due to the current pattern of ownership. For example, the engines on the ship are owned by the shipping companies and therefore it is not necessarily clear, who owns and possible pays for the use of engine censoring data. This data can be used for energy use optimization of the current vessel but also by the engine manufacturer and thereby also by other users of similar

[63] EU 2016. General Data Protection Regulation.

engines. When this ownership-of-the-data question is combined with the limited data transfer capacity onboard vessels, the sharing of continuous censoring data for the use of equipment manufacturers s not necessarily in the first interest of the shipowner.

Business risks related to opening of data were identified. "All data open for all" was considered as a risk for business and there is a lack of interest to share data. It was noticed that the discussion of open data is partly hindering development and should be replaced by the possibility to share only partial data and among agreed parties. This would require the possibility for user identification in the APIs.

Fragmentation of available data, incompatibility of authority systems and critical attitude of commercial operators towards open sharing of data have recognised as challenges in developing a shared data platform in the Baltic Sea area[64].

3.6.10 Lack of standards and standardized systems

Lack of standard ways of information sharing along the supply chain is a major optimization obstacle in the industry. There is a strong need for more fluent data exchange between vessels and ports and port state authorities but also a need for already existing digital systems to be able to change information. Some of the interviewees saw the missing of standards as the main problem while others saw no need for standards but more for an obligation to describe the APIs. This would enable data sharing between different data system without bigger data system integration.

A lot of development is ongoing related to data-based optimization and better exchange of information in the maritime industry. This has led to a vast amount of parallel and partly overlapping information systems. Incompatibility of these systems creates new bottlenecks to the industry. Interviewees brought up that for example in port if one operator has already invested in one digital system, they may not be willing to take whole port's common system into use. Several initiatives towards standardization of the logistics chain are underway. The overlapping standard development projects might in worst case create more obstacles.

Also, the incompatibility of different authority systems is a problem. This was stated in many levels, inside one county between different authorities as well between different countries and regions. For example, the EU's current, flag neutral Single Window system[65] was criticised for setting up a system where each EU country still requires vessels to fill in IMO documents in different formats. There was a strong need for standard format of information exchange between authorities so that same information from vessels could be used even within on country's authorities through one input point.

The Finnish Ministry of Transport and Communications (2016)[64] pointed out that in the Baltic Sea area information related to the maritime cluster is dispersed in several information systems and that information systems of the authorities are incompatible, which slows down both the feeding of information and its utility.

3.7 Identified measures to address challenges in digitalization

Another aim of the study was to identify measures to tackle the main challenges regarding digitalization as an emission abatement tool. The challenges were described in the previous chapter. The identified measures to overcome them are outlined below. The measures to consider in the further development are the following:

- Operational and institutional measures:
  - Focusing on the entire supply chain to ensure seamless transportation;
  - Creating incentives for voluntary data sharing;

[64] Finnish Ministry of Transport and Communications 2016. Digital Baltic Sea – a feasibility study. Publications of the Ministry of Transport and Communications 6/2016
[65] European Maritime Single Window. Accessed 04/09/2019

  - Developing freight contracts with new sustainable clauses to enhance optimal sailing speed and Just-In-Time arrival;
  - Converting waiting time in ports to sailing time at sea through more real time data;
  - Promoting innovative public procurements; and
  - Promoting discussion on digital disruption and creating a common understanding of the importance of digitalization in the maritime industry.
- Global harmonization of information sharing:
  - Enabling submission of all administrative information from a ship through one input point (single windows), cutting out overlapping systems;
  - Providing real-time access to authority/public data (e.g. transportation data);
  - Developing standardized ways for ships to communicate with ports globally and harmonizing descriptions of Application Programming Interfaces (APIs); and
  - Sharing selected data combined with electronic identification in interfaces.
- Technical measures:
  - Promoting the development of platforms and service-based business models and machine learning; and
  - Developing affordable technical means for ship-to-shore connectivity and sharing of real-time data.

3.7.1 Operational and institutional measures

According to the interviewees, the aim of digitalization in the field of logistics should be to create a truly connected and intermodal transport chain. Both cargo and information should flow transparently through the chain in order to improve energy efficiency. It was pointed out that e.g. seeing in real-time when cargo is arriving to port, when unloading takes place and when cargo is transported to the gate would enable much better optimization of port operations. This would induce savings especially in tramp traffic. Digitalization has a major role in this. Some interviewees proposed that ports should be obliged to report their cargo flow data in real time, in which the authorities were pointed out to have the power.

When aiming towards more open data sharing, the formation of data owning giants should be hindered. Measures are needed in order to make sure that the collected and shared data cannot be misused. It was highlighted that all the actors in the chain should be aware of the risks related to data sharing, and data sharing should be implemented by reliable means. It was also stressed that authorities should make their own public data open more real-time and not just as yearly statistics.

The interviewees hoped that possible harmonization or regulative measures should be implemented from the perspective of the whole chain and not only by regulating some parts of the chain. This might be possible to accomplish in some regions, e.g. in EU, but an international framework to regulate the whole supply chain does not exist. The interviewees expressed a strong hope that national authorities would recognise the need of harmonization of procedures on the global level. Regulating global industry from a national point of view rarely works. It was also pointed out that if any regulation concerning digitalization is introduced, it should absolutely be only on a concept level and never on a technical level.

The interviewees proposed incentive systems for the users of digital systems. They also pointed out that size matters also in digitalization; the bigger the company and the longer the chain it manages, the more digitalization tools they can develop and utilize. Especially the smaller companies need economic incentives to invest in digitalization.

The current freight contract models and clauses were considered challenging. However, the interviewees anticipated increasing pressure from both inside and outside the industry to modify the contracts towards environmental sustainability. Also, the role of cargo owners' environmental and emission strategies was emphasized as the initiators of change. The current freight contract models should be developed, and new sustainability clauses included. This will enable shipowners to use optimal sailing speed and JIT arrival.

Converting waiting time in ports to sailing time at sea was identified crucial in reducing sailing speed and therefore cutting emissions. This needs real time data of where the ships are sailing so that they can be in the right place at the right time. The authorities were recognised as important stakeholders in the issue. The interviewees pointed out that regulation through a neutral party would enable establishing the same rules for all actors. Only then can digitalization be a win-win game for all parties in the logistics chain.

Also, innovative public procurements are important tools to promote digitalization and emission abatement. The interviewees appealed for political decisions on requirements for zero emissions and use of optimization tools in public vessel procurements.

Promoting discussion on new digital business models and creating a common understanding of the importance of digitalization in the maritime industry was considered of the utmost importance. Public sector being an important initiator in this.

3.7.2 Global harmonization of information sharing

Unification of authority information systems, creation of single windows or at least creating interfaces between them was considered crucial. The information exchange between authorities needs a standard format to enable the same information from vessels to be used by several authorities through one input point. Several interviewees brought up that it is crucial to harmonize the way the ships communicate with ports in each country, which might need some regulation. Co-operation between national and international authorities is of utmost importance in getting the same systems for ports and vessels to be used in different countries and regions.

Due to many players in the industry, the need for standardized information exchange was brought up by many interviewees. However, it would be very hard to achieve since the standardization processes are long, complex and time consuming. Digital solutions are developing fast and there is no time to start creating standards which would be outdated after a couple of years. The aim should therefore be the usage of already developed and tested standardized data sharing formats instead of creating new ones. For example, the Port of Rotterdam is aiming at implementing the GS1[66] standards and the Swedish Maritime Administration the IHO S-211 and 421-429 series standards[67]. The interviewees see that the regulations should come from the IMO. The EU could also play a role, although the global international standards should be pushed forward. It was also pointed out that possible standardization should be introduced by general standardization bodies and not by service providers. However, before discussion on standardization is started, the supply chain data that should be shared needs to be identified.

Another solution for sharing data would be to further develop the documentation of APIs. Several interviewees saw problems with introducing obligatory standard data exchange formats and pointed out that if the descriptions of APIs would be made mandatory, data systems could interact with each other without the need of standardization. Incentives to use APIs were pointed out by many interviewees as a more effective way than creating complicated standard formats, which are slow to establish.

Security is an important issue in sharing and utilizing data. The parties need to be identified in system interfaces to be able to share the information only to those who need it. The electrical identification should be internationally standardized so that the users can be trusted and the access to systems can be limited to relevant parties.

Some of the interviewees saw that data sharing among the different actors will not take place without regulations, although regulation was not considered to be a solution to digitalization. Some interviewees stated e.g. that ports need to be obligated to open their real-time traffic information in order to advance optimisation of operations. However, it was pointed out that

[66] GS1. Standards used in transport management. Accessed 10/09/2019
[67] IHO. International hydrographic data model product Specifications. Accessed 09/09/2019

regulation should aim at opening data in a controlled manner. Instead of a strict requirement for "open data", companies should be required to open some "selected data". The interviewees saw that direct agreements and protocols on what data needs to be transferred and how are needed, and that public-private co-operation is crucial in achieving this.

One example of voluntary agreement on standards in small scale brought up in the interviews is the Smart Port Standard implemented by four ports in Finland, Sweden and Estonia and three shipping companies. This inherent co-operation has enabled compatible passenger and car gate systems in these ports and among the different shipping companies so that the different data systems recognize the same information and interact with each other. Further, an unofficial development model and the format for information flow have been created. This enables the systems to be different but the information format to be similar between the different actors.

3.7.3 Technical measures

Many interviewees pointed out that technically one of the most effective ways to enhance digitalization and achieve emission reductions would be to share data on a platform-based structure combined with machine learning algorithms and predicting analytics. Some of the interviewed parties regarded artificial intelligence for predicting cargo flows as a crucial measure.

The interviewees see that measuring and collecting relevant and real-time data from the supply chain is still needed as the basis for operation optimization. This could include e.g. the usage of sensors onboard to improve knowledge of fuel consumption in real time. Real-time information of dynamic variables such as weather, currents and ice conditions would be of great advantage in cutting down the emissions in the logistics chain. Also, Brouver et al. (2016)[68] present the idea of using operational sensor data from ships to better predict the delays in order to adjust the sailing speed of the vessel.

Interviewees pointed out that in order to gather and utilize data it is crucial to develop the data flow from ship to shore. The development of satellite data transfer and its pricing models, introduction of nanosatellites, 5G networks and more efficient usage of the radio network were brought up as possible solutions. In addition, better usage of the ship capacity and streamlining the traffic system were considered.

3.8 Impacts of identified measures on emission reduction

The assessment of impacts of the proposed measures on GHG emission reductions is based on literature review and results of the interview survey. The impact of each measure is strongly linked to how digitalization will change the current business and operation models in shipping. In case the current modes of operation, division of responsibilities and revenue generation models will not change, digitalization will probably have only a supporting role in reaching IMO 2050 goals. In case digitalization will change the current models of operation more profoundly, allowing real-time optimization of the whole logistical chain, it will most probably have a larger role on reducing GHG emissions.

Estimates on the emission reduction potential of different measures in recent studies vary a lot depending on their point of view. For example, Keefe (2014)[69] states that real-time data analytics can induce a 2-5 % reduction in fuel consumption. Wang & Nutsey (2013)[70] estimate that CO_2 reductions from e.g. better weather-based routing could have a potential for fuel reduction potential of 1-4 % and from optimised speed reduction up to 10-30 %. Gustafsson et

[68] Brouer, B. D., Karsten, C. V., & Pisinger, D. 2016. Big data optimization in maritime logistics. In Emrouznejad, A. (Ed.). Big data optimization: Recent developments and challenges. 18: 319-344. New York City, NY: Springer International Publishing.
[69] Keefe, P. 2014. Optimize Performance via Data Analytics. Maritime Logistics Professional Q1/2014. Accessed 15/07/2019
[70] Wang, H. & Lutsey, N. 2013. Long-term potential for increased shipping efficiency through the adoption of industry-leading practice. White paper. International Council on Clean Transportation.

al. (2019)[6] estimate that ca. 5 % of shipping emissions are directly generated in ports, but the indirect impact of ports on emissions is much higher as the inefficiencies in cargo handling result in more ships being needed to maintain the same transport capacity.

When talking about the potential for optimizing the whole supply chain and logistical planning with digital solutions, the estimates for emission reductions tend to be larger. According to Gustafsson et al. (2019)[6], real-time coordination of production and logistics planning would increase the utilization of bulk ships by 34-43 %, which could reduce emissions by 25-30 %.

The relative contributions of the different existing and scalable solutions to emissions reduction presented by Gustafsson et al. (2019)[6] are shown in Figure 7. The impact of different measures and solutions changes over time. The process should start by implementing voyage optimization and cargo flow coordination, both in which digital solutions are vital.

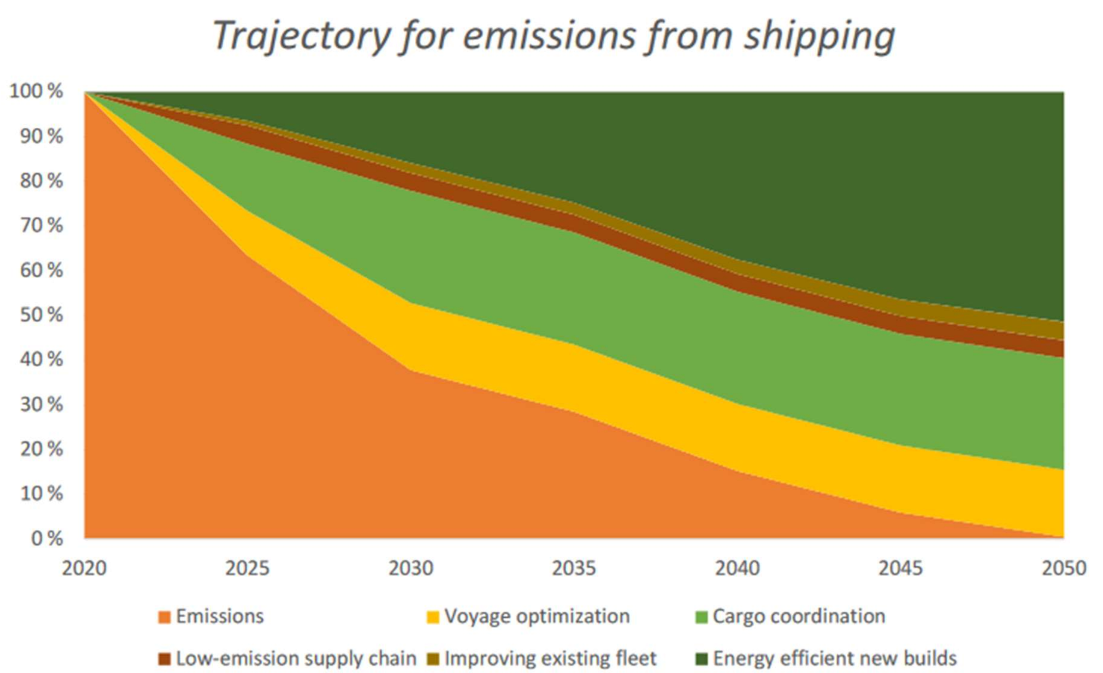

Figure 7. A proposed a trajectory by Gustafsson et al. (2019)[6] for reducing shipping emissions from their peak in 2020 until 2050. The figure shows the relative contributions of different solutions to emissions reductions and indicates a sequence of the various measures.

Impacts from identified measures presented in Chapter 3.7 are qualitatively evaluated in Figure 8. The measurements were classified on scales from easy to hard implementation and from low to high impact. The creation of new business models should be aimed at as it will have a great importance, but it is also one of the hardest measures to implement.

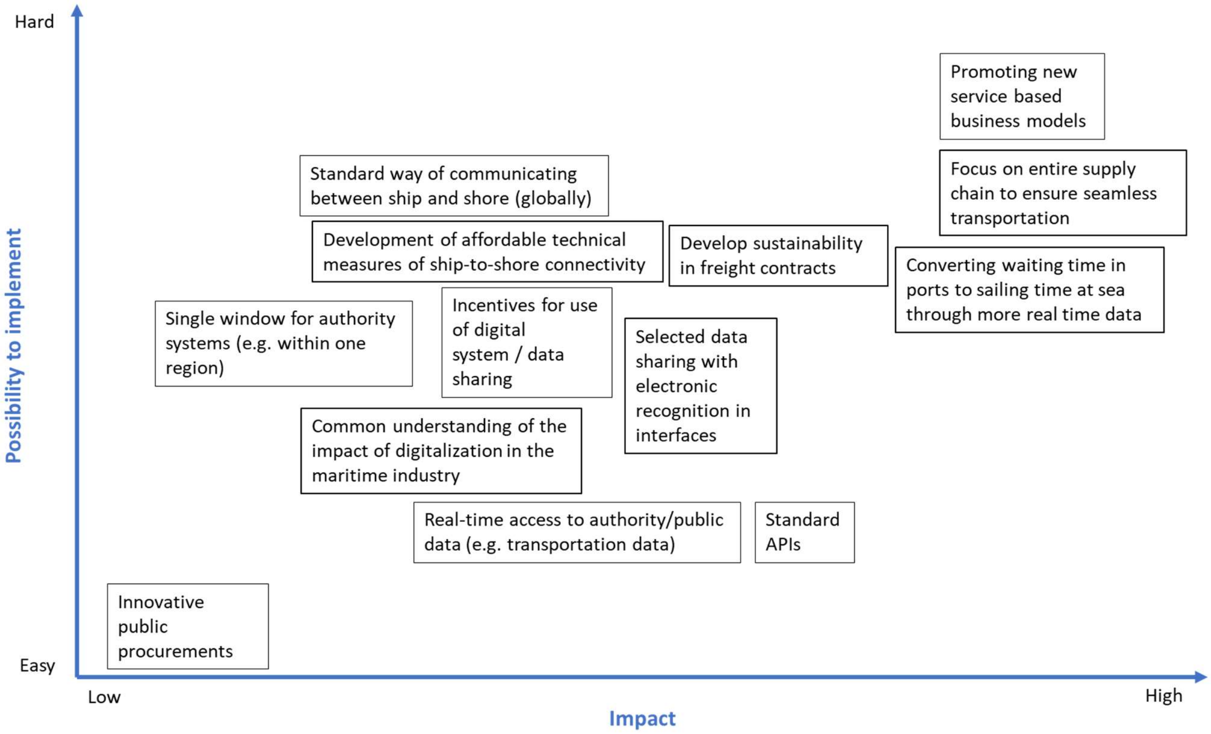

Figure 8. Impact and implementation possibility of measures to promote digitalization in GHG emission abatement. Measures based on the interviews.

4 Conclusions

The importance of digitalization on GHG emissions reduction can be considered on two levels (Figure 9). Firstly, digitalization is recognised as a tool for efficient information gathering, exchange and analysis. On the second level, digitalization and data-based systems are anticipated to cause disruption in the existing maritime business models. This would mean more data- and service-based optimization of the whole supply chain and possibly drastic changes in the current roles and ownership models of the industry.

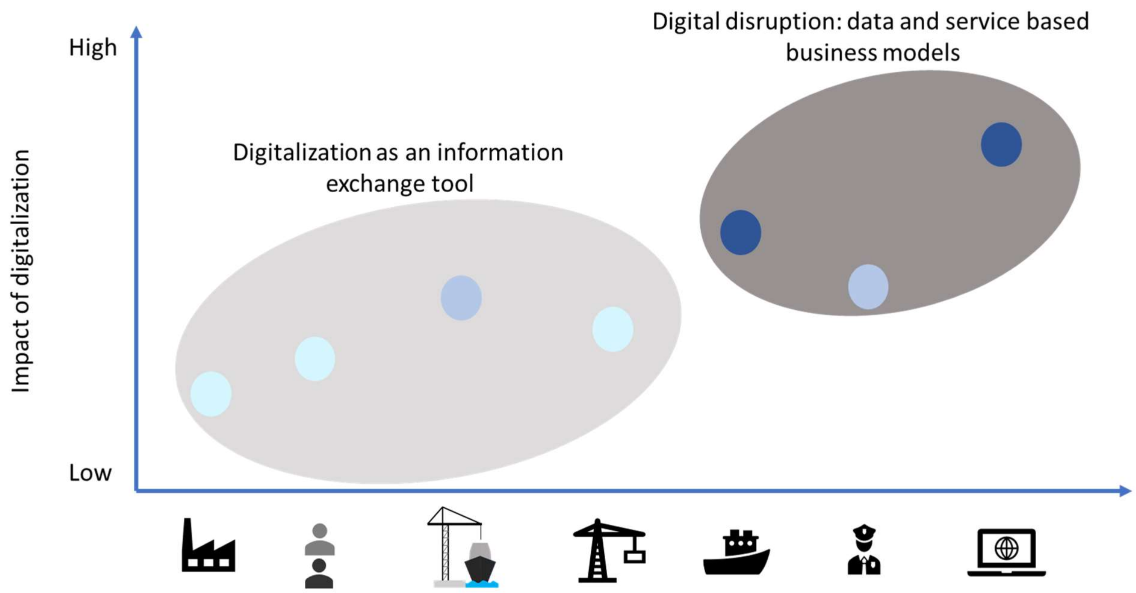

Figure 9. Evaluation of the impact of digitalization on GHG emission reduction based on the two different ways of implementing digitalization, n=23.

The industry faces several challenges which slow down the deployment of digital and data-based solutions. There is no common understanding about the future of maritime industry regarding reduction of GHG emissions and digitalization. Different actors are approaching digitalization from their own angles and how they as a company could benefit from it, instead of how the industry should be transformed by digitalization. Developing of overlapping systems which do not interact with each other creates yet another challenge to overcome. The industry is strongly guarding the status quo.

Digital sharing and analysis of data along the supply chain are prerequisites for optimizing operations and therefore also an important factor in reducing GHG emissions. A lack of data for the basis of optimization still exists. For example, there is a lack of real-time information of cargo flows and vessels calls. The supply chain already generates a lot of data, but even the existing data has no value if it is not shared among the actors, analysed and utilized especially in optimization of transport flows, storage capacity and port operations. The information exchange in the fragmented supply chain is currently complex and multi-phased involving several intermediate parties. Harmonization of data formats, promotion of application programming interfaces (APIs) and further developing vessels as platforms for remote data monitoring would be crucial in order to reduce GHG emissions. The information flow and data transfer from ship to shore and vice versa is still challenging due to limited data transfer capacity. Vessels rely mostly on satellite connections that are sometimes unreliable and not very cost-efficient.

The conversion of idle waiting time in ports to sailing time at sea is crucial in order to reduce energy consumption and emissions. Just-In-Time arrival or ecospeeding are recognised as efficient ways to reduce emissions. However, current contract models and revenue logic do not support this development. Rushing-to-wait in ports seems to be a tradition and forced by freight contracts. The current established freight contract models (i.e. charter parties) between charterer and shipowner do not allow or incentivize optimized energy consumption or port arrivals. The economic value of fuel savings is in many cases overrun by other economic incentives such as demurrage or the value of transporting the cargo to port on-time. The industry is also facing low willingness to invest in new technology due to a lack of market incentives.

Currently different actors are optimizing the information flow and operations inside their own sector, which is not efficient in terms of the whole logistic chain. Optimization and possible regulation regarding information flow should whenever possible cover the whole supply chain. Optimizing only parts of the chain easily creates problems elsewhere. If introducing regulation and/or incentives regarding digitalization, they should a) be technology neutral b) be as global as possible and c) promote fair copyrights and secure connections.

Further examination of challenges hindering the implementation of digitalization is required, and further actions need to be developed. Understanding how the entire maritime transport system will develop in the future is fundamental in defining emission reduction measures. Instead of single energy-efficiency measures, the scope of discussion among regulators and the whole industry should be wider.

It would be beneficial to include digitization to be one of the both short-term and mid-term emission abatement measures to reach IMO’s Initial GHG Strategy.

Appendix 1.

List of interviewees

Company	Interviewee
Awake.Ai	CEO & Founder Karno Tenovuo
BIMCO	Deputy Secretary General Lars Robert Pedersen
Cargo owner – international industrial company	N.N.
Finnish Ministry of Transport and Communications	Senior Ministerial Adviser Anne Miettinen
Finnlines/Finnsteve Ltd	Head of Group Purchasing Thomas Doepel
Hangö Stevedooring Oy/Ab	Managing Director Matti Esko
KNL Networks	Co-Founder & CEO Toni Linden
Kongsberg Maritime Finland	Head of Innovation & Technology Sauli Eloranta
Meriaura Ltd	Operator, Sustainable Development and Weather Esko Pettay
NAPA Ltd	Senior R&D Engineer Teemu Manderbacka, Director, Development Pekka Pakkanen
Nautic AI Ltd/Fleetrange	CEO / Founder Henrik Ramm-Schmidt
Outokumpu Ltd	Manager – Logistics Services Hannu Koivisto
Port of Helsinki Ltd	Development Manager Jussi Malm, Head of Sustainable Development Andreas Slotte
Port of Oulu Ltd	Finance & Port Digitalization Mira Juola
International Taskforce Port Call Optimization	Chairman Ben van Scherpenzeel
Seaber Ltd	CEO / Co-Founder Sebastian Sjöberg
Shipbroker/agency	N. N. & N. N.
Swedish Maritime Administration	Project Manager Jouni Lindberg
Finnish Shipowners' Association	Head of Environment and Technology Sinikka Hartonen
Tärntank Ship Management AB	Chief Executive Officer (CEO) Claes Möller, Senior Financial Adviser Dick Höglund
Finnish Transport and Communications Agency (Traficom)	Senior Officer Antti Arkima
Åbo Akademi University	Adjunct Professor (Docent) in maritime law and the law of the sea Henrik Ringbom

Appendix 2.

Key questions of the interview survey

- In your opinion, how should digitalization be utilized in reaching the IMO 2050 goals for greenhouse gas reductions?
- What are, in your opinion, the most critical information interfaces when talking about digitalization in the maritime transportation sector?
- What kind of challenges or obstacles do you see in the maritime transportation chain which hinder / slow down digitalization?
- What kinds of digital solutions/digitalization projects is your organization currently working with?
    - What kind of problems are these aiming to solve?
    - Which parties have been involved?
    - What kind of challenges have been encountered during the development?
    - If there have been some challenges/problems, how did you cope with them?
- Would you think Just-In-Time would be a solution in reducing the CHG emissions?
- Slow steaming and ecospeed; are these efficient in terms of the reductions?
- Is there, in your opinion a need for the standardizing of data?
- Who would be the party responsible of the development of standards in the field? EU? IMO?
- Are there obstacles to be overtaken?
- The division of benefits from digitalization; Who pays, who gains?

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