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Outlook on the transition towards autonomous shipping

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1 INTRODUCTION

Have you ever considered that we today take granted some things to operate autonomously without a crew yet this has not always been the case? An elevator, a subway or from the maritime sector a lighthouse might be such examples which have earlier had human operators. The maritime sector has lately entered into such a whirl that ships might at some point be added into the list. Some years ago software solutions to improve fuel efficiency or remote monitoring of equipment were key development areas and discussion topics in the industry. These discussions evolved into smart ship or even autonomous ship visions and also into real-life projects. For smart ships then usually IT technology improvements and connectivity were usually considered for different ship systems. For autonomous ships, the discussion progressed much further into visioning a remote-controlled ships with autonomously operating capabilities although not necessarily unmanned. Both of these views can be interpreted to represent the same development path which has now for progressed for some years. This report provides insight on this development path through the findings made during the Advanced Autonomous Waterborne Applications (AAWA) Initiative.

The initiative was launched in 2015 to explore opportunities around the idea of autonomous shipping from several directions. The overall goal was to address what could make autonomous ships a reality. The companies involved in the project (Rolls-Royce, DNV GL, Napa, Deltamarin, Inmarsat, and later additions Brighthouse Intelligence, ESL and Finferries) covered numerous types of technological and operational studies and applications on shipping and automation. The partnering research institutes' (University of Turku, Aalto University, Tampere University of Technology, Åbo Akademi University, and VTT) role was to provide more profound investigations and introduce insights not included in the company perspectives.

Authors from Turku School of Economics at the University of Turku carried out research and observations from the economic disciplines perspective and more precisely following approaches from innovation studies and industrial marketing. During the project the research was directed into autonomous shipping emergence as a larger phenomenon. As the phenomenon in question was very on-going during the project the research design faced recurrently alterations. Final shape documented in this report included three approaches which can be characterized to represent the past, the present and the future. The past on the events that have taken place until year 2017 have been documented through media follow-up during the project. Concerning the present, the different views in the sector during 2016-2017 are stated via different interviews, inquiries and media follow-up. For the future a tailored network visioning workshops were organized with project consortia to picture what kind of future is emerging. In the following contents of each chapter is described in more detail.

The slogan selected for the AAWA project in its starting phase in 2015, “Redefining Shipping”, indicates that the project is about something broader than a single technological innovation. The word *redefine* suggests that a new kind of approach to shipping will take place but it is also likely that the new definition nevertheless utilizes something from the previous one. The same applies to innovation in general, as new products or technologies do not appear from thin air but build on existing elements. Innovation theories and in particular the theory of sociotechnical transitions (Geels 2002) fit well to examine the possible next revolution in shipping: the idea of autonomous ships. In chapter 2.1, innovation theories introduce various factors, such as niche markets, infrastructure, regulation, critical events or macro-level trends, which affect how this redefining takes place and how technological change unfolds.

Overall, the Redefining Shipping -slogan acts as a vision for the maritime sector. Marketing theories, especially in the field of Industrial Marketing (e.g. the IMP group) help to understand various aspects of how new businesses emerge, and how complex candidates for innovation, such as autonomous shipping, might progress in an environment characterized by B2B relationships between different kinds of companies. Visions are tools for interaction in business networks to advance initiatives towards actual innovation. In chapter 2.2, insights from research on the management of business and innovation networks are presented.

Shipping refers most commonly to the transportation of goods by a carrier on land, air or sea, but due to the highest volumes and historical foundations sea transport is often emphasized with the term. In addition, the purchasing, production and distribution of goods are vital for global supply chains. Supply chain management is defined for example by Jones and Riley (1985) as the total flow of materials from suppliers to end users. Although sea transport - the shipping industry or sometimes the maritime industry - is a significant economic sector on its own, the supply chain perspective underlines that the maritime sector does not exist in isolation but is highly integrated in all economic activity and other transportation means.

Already for some decades shipping has faced steady increase in the degree of automation. And actually the first ideas for an unmanned ship were outspoken in the 1970s. These early developments are represented in chapter 3.1. During the last few years much attention has been directed towards the outcomes of digitalization in the events and discussions involving shipping and the maritime sector. In the aftermath of the financial crisis and continued downturn with low growth, cost-cutting and lack of investments, an anticipation of change has arisen. Simultaneously, there is a view that shipping has seen only incremental advances since the containerization. The anticipation is directed towards many digitalization-related concepts, e.g. smart ship, predictive maintenance, or electronic documentation. The actual names and terms for these concepts also often vary in different contexts. During the course of the AAWA project the maritime community has witnessed that the idea of autonomous shipping has spearheaded these discussions especially since 2016. It also compiles many of the mentioned ideas together. The vision of the future of shipping has become more precise, vivid and progressive. At the same time the anticipated turning point appears to be closer. In chapter 3.2, a timeline of the events related to the (re-)emergence of the vision of autonomous shipping is presented with a collection of declared projects, statements, tests and other actions. In chapter 3.3 different drivers recognized from the timeline and gathered media and industry conference to facilitate the transition towards autonomous shipping are summarized.

Characteristically, the maritime autonomous discussion in public has been largely driven by the technology side of equipment and system providers, communications companies or others. On the contrary, public comments from the potential users of autonomous technologies, e.g. shipowners and shipping companies, are quite rare. For our study, their existing comments and additional preliminary data has been gathered. Based on this data, five different characteristic shipping company profiles are presented in chapter 4 to illustrate the range of prevailing attitudes and the typical issues mentioned by different kinds of shipping companies and others in relation to autonomous technologies.

After covering what has happened so far in the transition towards autonomous shipping and where the companies currently stand, this report then takes a more future oriented approach. Using a synthesis of methods from business network research and futures studies, the results of network visioning workshops conducted with project's partner companies and others are presented in chapter 5. These results provide insight into how the technology suppliers and developers have envisioned the near future of autonomous shipping networks might become organized based on the information they know now and how they see the future could unfold. Chapter 6 summarizes the main findings and draws authors' conclusions on the autonomous shipping transition as a phenomenon.

2 BEHIND THE EMERGENCE OF AUTONOMOUS SHIPPING - INNOVATION AND BUSINESS NETWORK PERSPECTIVES

2.1 Concepts from innovation studies: technological change, sociotechnical transition and dominant design

The enthusiasm around autonomous shipping suggests that it is a promising case for a technological change, which in its simplest mode can be described with linear models of innovation. There is a classic debate between two alternatives. The *technology-push model* describes innovation to proceed from basic science to design and engineering, and progressing to production and markets. The *demand-pull model* takes the opposite view and sees market needs as a starting point for which engineers design new solutions that are then produced and sold. (see Godin 2006).

In the case of autonomous shipping with many maritime system providers taking an active stand, we see a resemblance with the technology-push model. This also gathers criticism that the phenomenon is driven too much by technology enthusiasm. Consequently, the market-pull side is something that the industry is now beginning to take more into consideration as the development proceeds. One of the key questions is how value is created from technological opportunities in a way that fits the cognitive and institutional settings in the market. More detailed innovation theories take on the market and societal perspective more accurately than these simple linear models. It is important to distinguish between *invention* (a technological breakthrough), *innovation* (a novelty that is fit for a market) and *diffusion* (the development of wide-scale market demand). Rogers (2003) has introduced the concepts of innovation adoption and diffusion often illustrated with an s-curve.

Considering technology adoption, especially information systems sciences have developed models for how IT technologies are adopted. The *technology-organization-environment framework* describes how a company or another organization makes decisions regarding technological innovations. Here, a certain technology needs to be beneficial, suitable and available. In terms of organization, the formalization, management structures, slack resources and communication need to be supportive of the new technology. As for the organization’s environment, for example market structure, demand characteristics, competition, infrastructure and regulation affect the decision-making. (DePietro et al. 1990).

Shipping and sea transport can be described as a large technical system (Hughes 1983, Mayntz & Hughes 1988) similarly to railway networks or telephone systems. Aside from the technical capabilities required to enable the operations - transport of goods - the key issue is the systemic nature of shipping. A single transport is not so valuable as such unless it becomes connected to other transports. Also, not only ships but ports, different equipment, waterways, documentation etc. are all elements that are needed in addition to their builders and users. Among these, a large amount of interactions and interdependencies take place which needs a high level of coordination as well. Due to this systemic nature of shipping technological breakthroughs do not advance linearly but through social organizations and forms. Also considering the construction of artefacts needed in the system, in this case high-end ships, the theory of complex products and systems (CoPS) (Hobday 1998) emphasizes certain features in the construction stage, e.g. the project-like environment with many different actors designing and collaborating towards the completion.

Evolutionary economics addresses technological change engineers as performing searches between different alternatives for components of such technological systems. To give a simplified illustration, a ship can be thought to include five systems: e.g. the hull, power generation, propulsion, navigation, and communications. Consider each of them to have only two possible alternatives. Such a design space would already lead to 2x2x2x2x2 = 32 different alternatives. Naturally, in reality the number of systems and technological alternatives for each of them is much higher making the design space larger and more complex. But technological development and engineering work can be seen as engineers “moving” within the design space through trial and error. The search is most frequent “near” the existing technologies. More distant technological alternatives are more complex to reach and require e.g. dedicated laboratories or other advanced resources (Frenken 2006). Market-pull starts to have an effect when different applications or use cases are explored. Technological search then leads to design modifications for different applications and technological variety increases. (Frenken & Nuvolari 2004).

When a new type of product is entering a market there is a tendency for different product designs (from the technological design space) to be tried out as part of the search processes. After trials and errors a selection and standardization to a single design occurs. Such a design is called a *dominant design*. This also changes firm behavior on the market. In the era of ferment, trials of different designs, there is a large number and variety of firms each trying to succeed with their own design. When the selection occurs, some design is preferred over others and the firm that provides the design gets a competitive edge to forerun on the market. Other (remaining) rival firms start to imitate the selected dominant design and the variety of designs available on the market decreases. This change from the era of ferment to dominant design also changes company strategies. Before a dominant design is selected other firms focus on product innovations. After the dominant design selection firms start to develop process innovations instead. (Abernathy & Utterback 1978). A compiled model for dominant design sees it as a nested hierarchy of technological cycles. What is also highlighted in the model is that interdependencies between systems, subsystems and their components are tightly and hierarchically linked with industrial dynamics. (Murmann & Frenken 2006). A famous case in innovation studies is the rival of VHS and Betamax videocassette recorders. JVC's VHS design was able to become a dominant design especially integrating market demand and production more tightly together by licensing its design's production to other electronics companies. It outperformed Sony's Betamax design even though it was the first on the market and technologically a slightly better design. (Cusumano et al. 1992).

Geels (2002, 2005) builds on the previous theories and many other social science approaches on technology and also on evolutionary economics. His concept of *sociotechnical transition* compiles a multi-level model of how a significant technological change takes place. On the micro-level innovation niches are novel trials of technologies for different narrow special uses and purposes. Many trials fail but certain technologies are able to succeed and they accumulate other niches for trial. As they gather more knowledge and evidence from different niches the new technology approaches an established sociotechnical regime (meso-level). A sociotechnical regime is the prevailing set of knowledge in the use of decision-makers of the so far prevailing "old" technological trajectory that is established and progressing (only) by incremental innovations. This set of knowledge is influenced by various factors, such as current business and supplier networks, science networks, institutions, habits and other constraints. On the macro level the so called sociotechnical landscape brings out forces from the society that influence the sociotechnical regime and attitudes towards technologies. Policies, large societal trends (e.g. migration), or critical events (e.g. accidents) might affect how the new technology is treated. If the emerging new technology fits well enough into the sociotechnical regime, it turns into a dominant design and starts to break through and change the prevailing sociotechnical regime. When the new technology reshapes the sociotechnical regime it also has an influence on the sociotechnical landscape; in other words, technology changes society. Recently the framework of sociotechnical transitions has been mostly extended to examine how understanding on innovation would support the adoption of more sustainable technologies (Foxon 2013). Such changes could also be labeled as sustainability transitions (Geels 2010). Bohnsack et al. (2014) give an interesting example from electric vehicles in the early phase of such transition. Although many change ignited from the entrepreneurial firms incumbents have also been very active developing new technologies and business models from the start. This is also interesting for the maritime sector which kind of industry dynamics will follow and which kind of ecosystems will emerge.

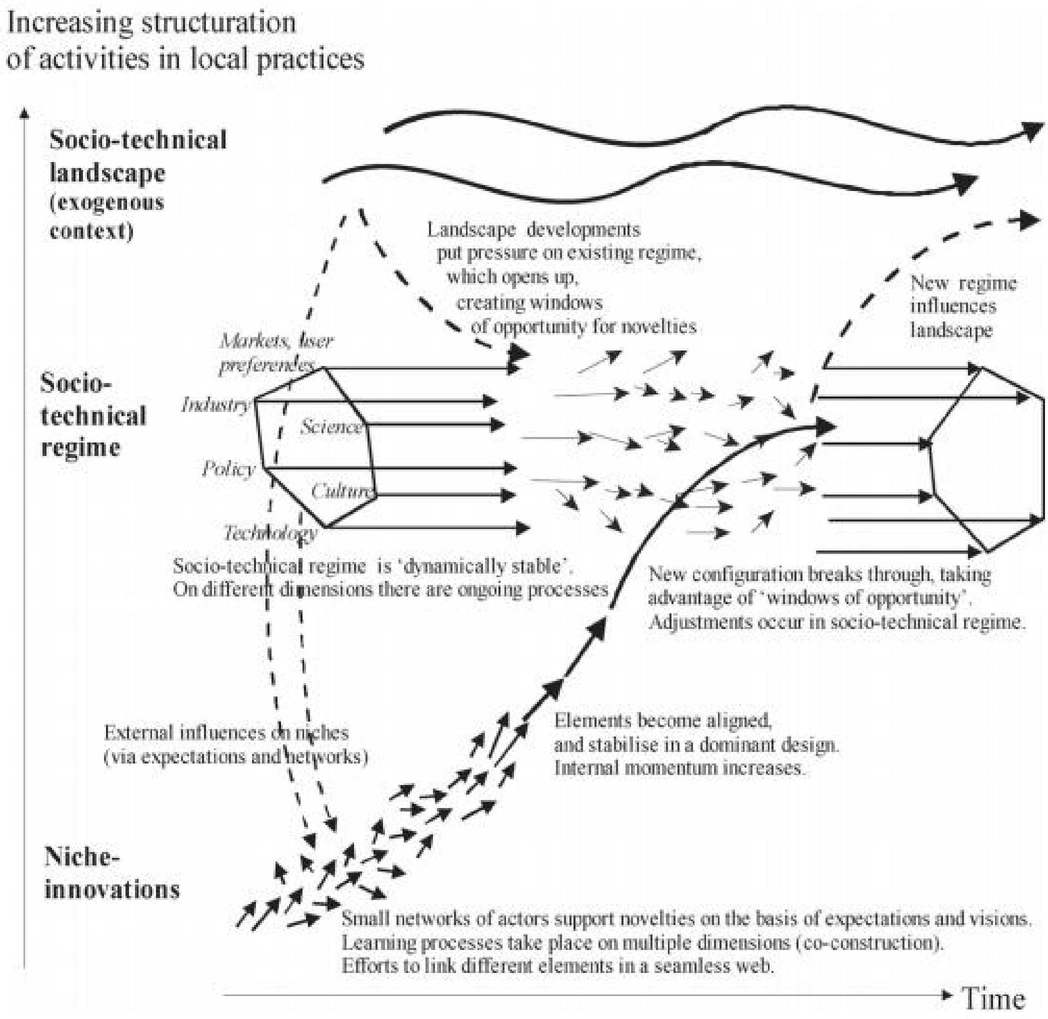


Figure 1 Multi-level perspective on sociotechnical transitions (Geels & Schot 2007 p. 401)

In the history of the maritime sector there are some examples of such gradual transitions or systemic innovations. Maritime historian Kaukiainen (2001) has pointed out that the development of communication technologies such as the telegraph and the increase of speed and coverage of information transfer have largely affected shipping and its freight rate throughout history. In other words, any innovations that improve or expand the flow of data and information are important. Containerization (see Levinson 2006) which began at the end of the 1950s is a great example of an operational revolution where the technological element in principle is quite simple. Yet the real novelty of containerization relates to the process and organizational improvements.

2.2 Network view on new business emergence

As shown previously by the literature on innovation and technological change the relationship between markets and technologies is complex and involves a number of actors. Research on industrial marketing illustrates that a range of networks between individuals, organizations and societal actors influence how technologies develop in different stages. The research field starting from the 1980s emphasizes that businesses and their development cannot be seen as merely a series of transactions but rather as complex and dynamic relationships between different organizations in interaction. (See e.g. Håkansson, 1989; Lundgren, 1995; Möller & Halinen, 1999; Möller, 2010).

Möller & Svahn (2003) and Möller & Rajala (2007) introduce the concept of strategic nets as intentionally formed network organizations where business actors interact but also have their own goals. Möller and Rajala (2007) suggest that there are different types of strategic nets based on their value creation logic, and they hold varying levels of significance for the firm and its business. Different types of strategic nets also have different management requirements. *Current business nets* continuously function on a well-known value creation logic, whereas *business renewal nets* aim to improve the processes of current business. These two categories represent knowledge exploitation (March 1991) striving for efficiency and optimized utilization of existing resources and processes. In the case of autonomous shipping transition, the third category of *emerging business nets* represents knowledge exploration which is about finding new business and bringing it to the market.

Within emerging business nets three sub-types are recognized. *Application nets* is about finding different applications for a new technology or a business. These are important for gathering experience and additional knowledge from experiments and testing etc. performed for example in collaborative projects. In *dominant design nets* (see previous chapter) firms seek opportunities to influence other actors. Setting and communicating agendas within the net is a tool to align the net towards a common goal e.g. standards. Emerging business differs vastly from current business by having more uncertainty in terms of value activities and actors, radical changes in the value creation logic, and new actors involved. Also *innovation networks* are important to link science-based information and new expertise to create radically new value solutions not known beforehand for the actors.

Figure 2 Different types of strategic nets of a business and its value creation logic (adapted from Möller & Rajala 2007).

Related to these business nets, Möller (2010) specifies utilizing the framework of sociotechnical systems for understanding how within emerging business fields sense-making and agenda construction between businesses and their managers happens. Sense-making implies that managers do not simply pick any new idea immediately into use but they have limited time and other resources to perceive and construct meaning to their observations. *Agenda construction* on the other hand is explained as constructing and communicating an attractive agenda for customers, other partners and stakeholders, thus influencing their sense-making. When successful, the agenda provides a credible development path of an envisioned new business field which offers potential value for the agenda-setter's partners. When the joint agenda is feasibly framed for the partners it generates commitment and lock-in to the same development path. Möller and Halinen (2017) also note that for such agenda construction and new value creation in networks to take place it must be supported by mutual transfer and creation of knowledge, negotiating actor roles as well as coordination and setting joint goals.

Regarding business networks, recently especially in industry conferences and general business discourse the ecosystem concept has risen as a commonly used term, which has had an influence on research as well. Nevertheless, Aarikka-Stenroos and Ritala (2017) point out that many aspects about ecosystems have already been theorized and studied in the network management research in industrial marketing. They provide examples of how in the literature the ecosystem concept is linked to business, innovation, start-ups, platforms and service prefix in research alone. The authors propose that the ecosystem is a new layer in the B2B network management framework, emphasizing that the networks are constantly altering with their surroundings, and partly open-ended and unstable. In an emerging business field like autonomous shipping, this rapidly changing nature of business networks is present in our research findings as well.

3 FROM MARITIME AUTOMATION TO AUTONOMOUS SHIPPING

3.1 A brief history of events towards autonomous shipping

The autonomous ship is not appearing out of thin air as notable increase in automation has already taken place in shipping especially from the 1960s onwards. In the 1970s systems, processes and regulations for a periodically unmanned engine room was developed (Innovation in the maritime industry 1979). The development of communication technologies replaced radio operators aboard. Later, navigational equipment advanced by the 1990s with different autopiloting and positioning systems as well as ECDIS (Electronic Chart Display and Information System). Also, the introduction of AIS (Automatic identification system) further reduced the need for standard communication. This has simultaneously reduced the number of crew needed especially for machinery operations. (Bertram 2002). National Research Council (1979) report on maritime industry innovation distinguishes between Japanese and Scandinavian approaches to maritime automation in the 1960s-1970s. Japan’s driver for increasing automation was the shortage of maritime manpower and therefore ship design aimed for minimum manning requirements. The Scandinavian approach was to keep some of the manpower but use the resources freed by automation for e.g. improved maintenance and training for efficiency and safety.

Before the (re-)emergence of the unmanned ship discussion during 2010-2012 the scope of automation was largely to do with capabilities such as equipment monitoring and predictive maintenance. An important driver for this was the keen goal for fuel efficiency under the poor and continued market situation after the financial crisis. Software-based services e.g. by Eniram, ABB’s solutions, or Marorka grew already before the autonomous shipping boom. This increased the standards for analytics and data-gathering in the maritime industry, which later turned out to be a supportive and still ongoing driver for the autonomous shipping vision as well.

Bertram (2002, 2015) provides a thorough overview regarding early projects in some way considering autonomous (unmanned) ships and the developments leading towards them. The first occurrence is by Schönknecht et al. (1973) which included the master-slave ships as a convoy in a book considering future ship concepts. In Bertram (2015) and occasionally in industry media, a Japanese Intelligent Ship project is mentioned to have taken place in the 1980s. Also, Finnish Kai Levander is mentioned to have had an unmanned vision for short-sea shipping in 1994. Bertram (2002) lists several studies made in Germany in the 1990s including several of his own. Many of these studies already found many technological possibilities to exist for e.g. remotely controlling ships but operational challenges and issues such as maintenance were out of reach for technological combinations available at that time. For the U.S. Navy, Ditizio et al. (1995) illustrated ways for reduced crew in a naval vessel. Bertram (2002) introduces how the U.S. Navy used the 1995 cruiser USS Yorktown as a "smart ship" testbed of contemporary standards. Automatic systems were used to reduce crew size. During testing, a computer crash made the ship nonfunctional at sea. Nevertheless, it was shown that a cost saving potential existed and system errors could be traced and fixed with adequate testing and backups.

So, the idea and vision of autonomous ships had already emerged in several occurrences in the past. However, it is not a direct linear trajectory as there are gaps when the idea was not at least publicly progressing. It can therefore be argued that the unmanned/autonomous ship re-emerged into industry discussion in 2012-2014. Two main triggers can be recognized for this. First, the launch of the MUNIN EU project[1] shows that the older visions were known in the industry and the time was ripe to re-evaluate and develop the idea. Secondly, the system provider Rolls-Royce gained wide attention not first from industry media but mainly mass economic media. One of the initial messages was that technological opportunities are now further along to fulfill those visions. What had changed is not necessarily fully known to anyone, but connectivity advances and the overall digitalization sweeping over most industries and the society most likely had an effect. For example, the breakthrough of the smartphone might be the kind of everyday experience affecting the wider public opinion of what is possible.

[1] MUNIN – Maritime Unmanned Navigation through Intelligence in Networks, http://www.unmanned-ship.org/munin/

3.2 Recent timeline for autonomous shipping in 2012-2017

As noted, the vision of unmanned ships was thought on several occasions but re-emerged as a global media topic in late 2013 and early 2014. For this report, 260 media articles and 61 conference or seminar presentations since the 2012 introduction of the MUNIN project have been traced, archived and analysed. The articles can be divided into two categories: mass media and marine industry media. Mass media includes several main global media, e.g. the BBC and CNN in addition to economy-focused media such as the Financial Times, Bloomberg, The Economist etc. Marine industry media include e.g. Lloyd's List, Hellenic Shipping News, Tradewinds News and The Motorship. Articles were selected with a keyword search "*autonomous ship**" or "*unmanned ship**" in October 2017 with a few individual additions discovered later after the actual searches. Also during the AAWA project, a systematic collection of news took place involving the keywords or main maritime system providers engaged in the autonomous ship development (e.g. ABB, Kongsberg, Rolls-Royce, Wärtsilä). In addition to media articles, presentations and materials from industry or research conferences were also collected. Such conferences include for example MUNIN project workshop at SMM trade fair in 2014, Autonomous Ship Technology Symposium in 2017 and Zooming in on Autonomous Ships seminar by Danish Maritime Authority in 2017.

The time period under investigation for the autonomous shipping phenomenon was selected to begin from September 2012, which is when the MUNIN EU-project was launched. The timeline in Figure 1 is divided into four sections and parts. Starting from the bottom of the figure, the lowest section holds launches of main projects for autonomous ships. The second section includes project highlights, pilots or demos that have been presented to the public. The third section includes strategic actions by key companies, governments or other actors. These include investments, partnerships, opening of new sites or working groups and other critical events. The opinions in public section at the top covers some overall remarks about how the discussion in the media has progressed. Usually the discussions were formulated by speakers and panels at an industry conference, which were then summarized by media with possibly some additional comments.

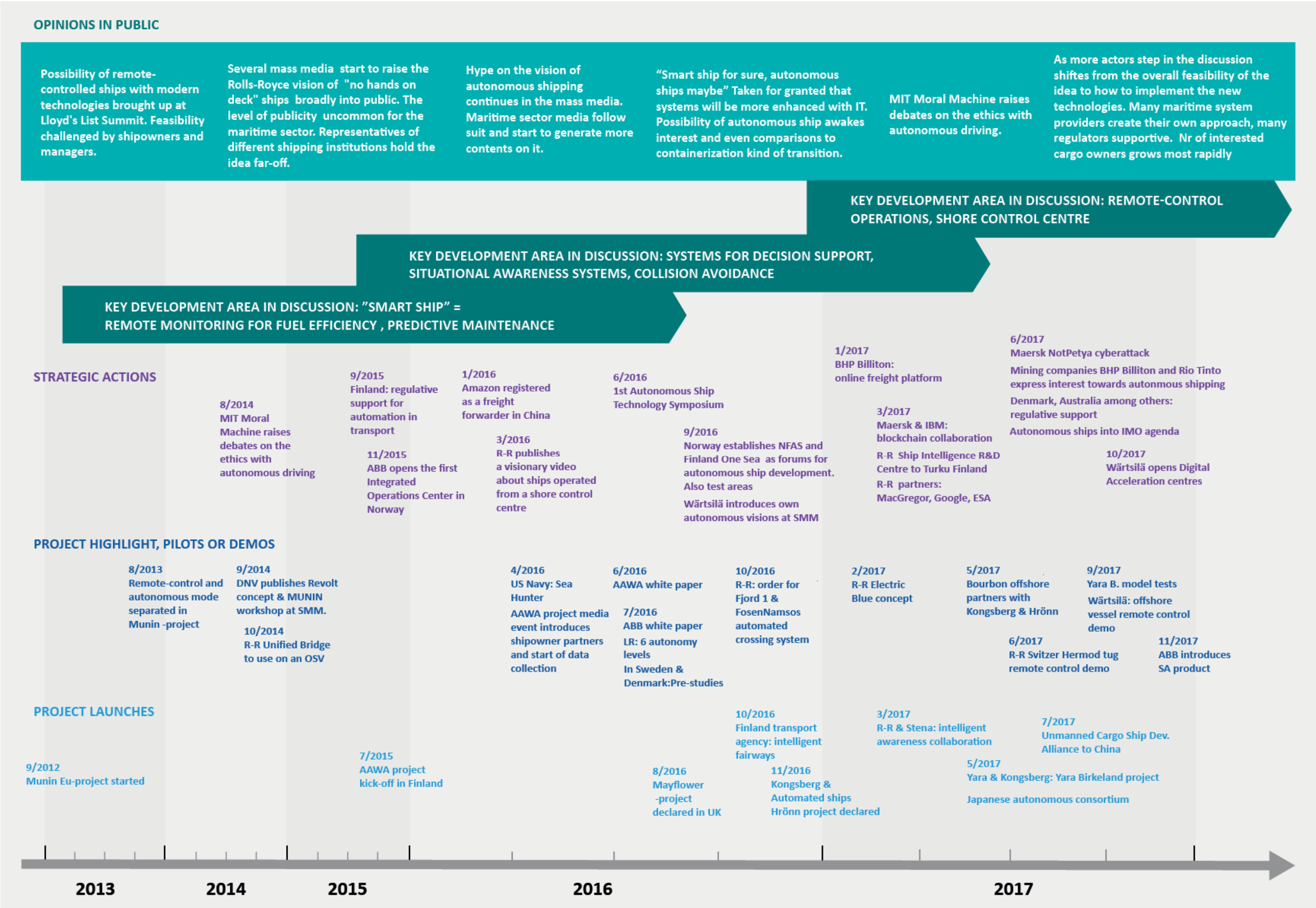


Figure 3 Timeline of key events related to emergence of autonomous shipping related initiatives during 2012-2017

By examining the events more closely, different goals can be identified in the background of all these events. Many actions drive towards general technological goals, e.g. basic and applied research taking place with the aim to find the right questions and feasible solutions for individual systems' performance to reach a desired level, and to integrate systems together. Some of the projects also have application-specific goals, e.g. the co-operation between Rolls-Royce and Stena is exploring opportunities for supportive systems for ferries rather than directly new ship designs. These different applications accumulate knowledge and experience for higher-level systemic innovations. Other events aim for regulation-related goals such as formulating working groups for preparing regulation changes or introducing themes to the IMO agenda. Business strategy related goals relate to events where key companies expand or introduce activities to increase R&D volumes or otherwise gain momentum as an industry transformer.

To summarize the early events from 2012 to early 2016, this was a phase when a hype surrounding autonomous ships was generated in the media and public discussions. Quickly after this, some of the main initiatives were launched, e.g. MUNIN and AAWA projects and the DNV GL Revolt concept. During that time mainly (maritime) technology developers were evaluating whether autonomous shipping was something worth considering. After the initial setups it was time to begin influencing customers and the wider public as well. Rolls-Royce received a surprising amount of attention for a maritime system provider in the mass media. Examples created in the automotive, aviation and other industries led people to ask why digitalization-led changes could not happen also in the maritime sector. Following the media interest, Rolls-Royce progressed to gradually create its own vision for autonomous shipping. One highlight was a video published in March 2016 showing a shore control centre solving a machinery failure on an autonomous ship. The video or images from it was vastly utilized later also by other organizations. The vision game was quickly continued by Wärtsilä introducing its own visionary designs and concepts at the SMM maritime fair in September 2016. ABB also highlighted their own approach in 2016. These visual elements were complemented with other published contents describing the thinking and approaches mainly via white papers. The AAWA project position paper was published in summer 2016 emphasizing different approaches to autonomous shipping, while ABB described key issues of the industry's changes in autumn 2016.

Next, project outcomes or highlights followed in the form of pilots or other actions starting to fulfill the visions declared earlier. The AAWA project announced collaboration with shipowners Finferries and ESL by sensor data collection. Simultaneously, the US Navy's Sea Hunter provided an advanced military example. The Norwegian Fjord1 and later FosenNamsos Sjø ordered automatic crossing systems for their new ferries from Rolls-Royce. In 2017, actions followed with several new milestones. Levander (2017) summarized Rolls-Royce visions regarding autonomous shipping highlighting that there will be versatile versions of autonomous ships depending their use case and lot of additional services and functions. Other shipowners and also cargo owners declared their interest in autonomous ship technologies and entered into collaboration projects or partnerships with system providers and others. By summer 2017, Stena Line, BHP Billiton and MOL Line were announced to collaborate with Rolls-Royce. The Norwegian chemical company Yara announced to be developing a new autonomous capable container feeder with Kongsberg to substitute truck transport from its plant in the so called Yara Birkeland project. The first remote control tests were also published in the summer. Rolls-Royce and the world's largest tug company Svitzer demonstrated the remote control operations of a tug near Copenhagen in June. Following this, Wärtsilä published similar tests for an offshore supply vessel in September. In November ABB was also announced to have been collecting data and performing testing aboard another Finnish small ferry in Helsinki.

3.3 Recognized drivers for autonomous shipping

As the discussion around autonomous shipping has progressed syntheses have begun to appear on how the development is thought to proceed. For example, Emblemsvåg (2017) emphasizes that while an autonomous ship might have clear benefits in terms of operational expenses of the ship, he also reminds that technologies, regulation and the demand-side must still mature before major changes are actualized. Based on the articles and other collected material for the timeline, the following technologies or elements below can be seen to support the vision and discussion on autonomous shipping.

- **Connectivity**: Ships and the maritime community have become much more connected in the 2010s than ever before due to the development of satellite communications with higher bandwidth. Ever more ships can enjoy an internet connection even for crew, although still not at all times. Also in cellular networks people have become accustomed to e.g. allowing high bandwidth and 5G is also on the horizon.
- **e-Navigation technologies** like AIS (Automatic Identification System) and ECDIS (Electronic Chart Display and Information System): The AIS system includes equipment and standards for most vessels on international voyages to transmit signals with identification and navigational information to be utilized by VTS (Vessel traffic services) and other vessels and users. Starting from 2006 it gradually came into widespread use, which also made free-to-use online ship tracking services possible.

Before AIS information of ship movements globally was much more limited. In addition to supporting navigational safety, AIS significantly increased transparency for the whole shipping industry. Different business intelligence and big data applications followed. ‘

ECDIS systems and their electronic charts have replaced paper charts and have developed into standard electronic approach to provide navigational data on a ship’s bridge. Envisioned in the 1980s, tested in 1991 and certified for professional use in 1999 the ECDIS system gradually diffused into widespread use in the 2000s (Williams 2017) . ECDIS has been stated to gradually become obligatory for almost all larger vessels in the future. As a major e-navigation standard into which present seafarers are trained into it acts also as a starting point for remote monitoring and controlling of vessels. The increase of different systems and their features on the bridge has however raised some critical voices from the user’s perspective, arguing that the systems become too complex or require more training and skills than before.

- **Equipment monitoring:** Before the idea of autonomous shipping emerged into the maritime industry media and conferences, many equipment manufacturers and system providers were interested in the development of data collection and remote monitoring of their equipment. Additionally, some new service providers emerged focusing on analytics and performance optimization especially for fuel costs and vessel performance.
- **Predictive maintenance**: The next step from monitoring was to also utilize the data streams for operational activities such as maintenance. The idea is to also optimize different cost-generating activities based on actual data and carrying out maintenance beforehand to keep the equipment in good condition. Before this, mainly predefined rules were followed which might lead to overperformance in some area or neglecting another area due to the lack of data. This relates to many equipment manufacturers shifting their focus during the last decade more towards advanced services. In addition to equipment, many companies have built capabilities for offering not only equipment but whole solutions including e.g. data and analytics as part of maintenance services.
- **Dynamic positioning:** As seen by the timeline among the companies launching initiatives are many of the providers of propulsion systems, e.g. ABB, Kongsberg, Rolls-Royce and Wärtsilä. Those companies also have several other systems in their portfolio. One key reason why those companies are involved is that they already possess technologies for providing DP (dynamic positioning) systems. Especially vessels that are

used for offshore applications are often equipped with DP systems which keep a ship's position and course constant in varying sea conditions by using the vessel's propellers. From first experiments in the 1960s, the number of DP vessels started to increase during the 1980s. Technologies have then evolved offering more precise and maneuverable capabilities for the vessels. As the DP systems use automation of different navigational and maneuvering equipment for keeping the vessel in a single position, the logic is that similarly the same technological base could be used for ship movement remotely or autonomously. (gCaptain 2009).

- **Different special niche applications:** Several very specialized technological fields support the autonomous shipping as well. The offshore industry has long experience using remote and autonomous underwater vehicles for seabed surveys and other tasks. Also different boat-size remote or autonomous surface vessels are used for e.g. oceanographic research. On the military side applications for e.g. mine warfare or surveillance have been developed.
- **Electric propulsion:** Similarly as in hybrid cars, electric or hybrid propulsion utilizing batteries have gradually become an option also for smaller vessels. Especially ferries are suitable for them due to short-voyages and the ability to charge batteries during port stops. The first battery ferry for full-scale operation was built in 2014 for Norwegian waters and many more are following especially in the Northern Europe. Electric propulsion is a tempting candidate for autonomous shipping as it would make the systems architecture more simplified with less need for maintenance. Among the undergoing autonomous ship projects Yara Birkeland has incorporated the idea of electric propulsion.
- **Automotive sector as an inspiration:** Already starting from the 1980s car manufacturers have introduced major projects towards autonomous cars. More and more automated functions were developed (e.g. adaptive cruise control emerged at the end of the 1990s) and by the 2010s the number of different autonomous driving initiatives went sky-high with practically every major automotive company involved, with the addition of companies like Google. With this development for example sensor technologies and their supply has rapidly scaled up, which also helps maritime autonomy. The automotive examples have ignited discussions around regulation and ethics as well (e.g. the MIT moral machine).

4 PROFILES OF SHIPPING COMPANIES ON AUTONOMOUS SHIPPING

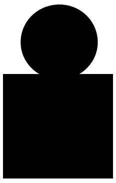
4.1 Background and methodology for the profiling

As seen from the timeline in chapter 3.2 maritime autonomous development accelerated especially starting from 2016 in the media and different events. Many maritime sector conferences quickly adopted autonomous ships as a frequently repeating theme. However, until more recently, what has stood out from many event programmes or media outputs is that public expressions of views or opinions from shipowners, ship operators or ship managers have remained quite scarce. The discussion and visioning so far has been promoted mostly by system and equipment providers and on the other hand regulation-related stakeholders such as maritime authorities. Shipping companies have not taken a stand at large and in detail. To summarize, until early 2018 the large majority of shipping companies have not yet been involved publicly in the discussion and visioning of autonomous technologies, some have expressed a very general level of interest, and only a narrow few have engaged in any activities with the theme.

A sub-research task in the AAWA project was to map the attitudes and orientation of shipowners, ship operators and ship managers towards the autonomous shipping and the technologies enabling it. During the process it became clear that this was not a straightforward task as many firms tend to keep a low profile when it comes to reimaging future shipping and their positioning towards the rapidly progressing phenomenon and majority of owners ignored to comment directly to the theme. The data set that was able to be gathered was a combination from different qualitative sources. As primary data from 15 interviews and e-mail enquiries on shipping companies and 61 industry conference presentations different level data is included in the analysis. The companies represented shipping activities globally. Around 40 of the presentations and possible questions and discussions related were also observed on-site (in Autonomous Ship Technology Symposium in Amsterdam and Zooming in on Autonomous Ships seminar in Copenhagen both in 2017). This was complemented and expanded by secondary data from media-searches and continuous follow-up of the topic to include various media articles from 2007 to 2017. The 260 media articles used to support the profiling are the same data set used and described in chapter 3.2 for the event timeline. The data set includes some main global media and economy-focused media sources but majority of the articles were from marine industry specialize media like Lloyd's List, Tradewinds News, Hellenic Shipping News and The Motorship. Keywords used for the searches in the marine media were "*autonomous ship**" and "*unmanned ship**". In a few of the articles term like "*smart ship"* might have been used more broadly instead but either of the search terms still was included in the text. The continuous follow-up focused on key companies in the field like from maritime system providers the companies recognized most active ones like ABB, Kongsberg, Rolls-Royce and Wärtsilä as well as major ship owners like Maersk. Through follow-up news on interesting events were detected and useful supportive material on maritime digitalization was collected. The final combined data set included heterogeneous observations from out-spoken comments or opinions from 65 shipowners, ship operators and ship management companies worldwide. NVivo software was used as a qualitative analysis tool to structure the data and categorize similar articles together.

Based on that data the following categorization includes four different profiles among the present market stakeholders and one profile coming from outside the core shipping industry boundary. A summary of the five profiles is presented in Figure 4 and each of the profiles is examined more closely in the following subchapters. We do not claim that this categorization is detailed and inclusive of all different types among the shipping stakeholders but rather a first attempt to profile shipping companies according to their perceptions, orientation and actions taken so far. Also, we keep the anonymity of the target companies protected and do not identify specific firms. It should be noted that some highlights with a reference to some company type are not taken on what is the exact composition of each profile group. Rather their purpose is to give character to the overall picture based on limited available data as opposed to providing any detailed descriptions or predictions.

RELUCTANT TRADITIONALIST



§ Not interested and no actions taken
§ Very reluctant and suspicious
§ Emotional, even romantic reactions to shipping
§ Sees no impact to core business which is to sell and buy ships
§ Smallest and leanest organization
§ Especially unease about indirect effects
§ Dominant owner group

OBSERVER

§ Never a first-mover, wants to be a second mover
§ No actions taken so far
§ Mixed views on the benefits and challenges
§ Observing others, learning and monitoring development in the market
§ Eyes on the competitor actions
§ Risk-avoidance central
§ Avoidance of development costs

SYSTEM-SPECIFIC DEVELOPER

§ Interested in autonomous development in a narrow role
§ Autonomous SHIP is not the first tier goal
§ Very controlled steps related to selected systems
§ But willing to engage in system-level testing and piloting and can focus resources
§ More likely for larger vessels like large ferries or cruise ships

RETHINKER

§ Autonomy is considered for a first-tier position in strategy
§ Ongoing testing and investment analyses
§ Going for a detailed plan for autonomous business
§ Willing to rethink whole vessels or operation models
§ Small vessels like tugs, small ferries, workboats easier first
§ Concept planning can already consider large cargo services

NEW ENTRANT

§ Actors outside traditional shipping or maritime players
§ Willing to speed up autonomous development in supply-chain level
§ Belief in systemic opportunities
§ Most sophisticated utilization and synergy from digitalization in general
§ Grand scale cargo owners or IT conglomerates might play a role

Figure 4 Portray of identified shipowner profiles in terms of attitude and orientation towards autonomous shipping

4.2 Reluctant traditionalists

The main reaction of this group towards autonomous technologies is that we do not need them. This is still by far the largest of any of the groups. The reluctance or indifference presents itself in various ways. Firstly, some companies with small organizations and thin resource pools consider autonomous technologies still to be too far in the future, a far-futuristic phenomenon. All available scarce technical and development resources at their disposal are needed in more practical and immediate cases.

Secondly some shipping companies, mainly non-operating owners, have outsourced many business processes and functions to different kinds of management companies and are thus separated from the development of many systems or processes. Such owners act more only as investors e.g. speculating with freight rates and vessel prices. If the timing of decisions against the market is the main area of interest then it can be concluded that such actors might also be in principle quite indifferent at this point to care if a vessel is a conventional or equipped with autonomous technology. On the other hand some ship management companies partnering with such shipowners might keep a low profile and keep distance to autonomous technologies for to not allow technology providers to have more power over their business. In other words, some of the actors don't have built-in need for development efforts.

Thirdly, some decision-makers among the maritime sector uphold emotional or even romantic ties to seafaring and shipping especially from people with a own career background as a seafarer. The background and traditions create a framing effect - a cognitive bias. This happens especially when fully unmanned ships are discussed and simultaneously partial developments like supportive systems are skipped. The industry cannot be imagined without its typical elements and especially without the seafarers themselves. Visions that suggest changes to traditional setups are resisted because things have always been in a certain way. In such situations seafaring and everything related to moving ships is considered over the business of transporting goods. This might in some cases result in some not entering the discussion around autonomous technologies at all because the basic principles of shipping are hard to reimagine for them.

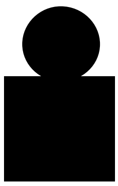
Based on the collected data on key characteristics of Reluctant Traditionalists, we can list the following profiling factors for the group (see also Figure 4 for the summaries of all groups and Figure 5 for group characterizations):

- Has not taken actions towards adopting autonomous technologies and is not interested to do so in the near future
- Relatively fewer actions towards gaining external knowledge
- Eyes on the competitors as an information source
- Lower top management risk-taking

- Views on the market environment more turbulent and high price competition pressure
- Less organizational support for autonomous technologies (resources, management support, skilled labour, experiments)
- Fewer benefits seen associated with autonomous technologies
- More challenges seen associated with autonomous technologies (especially high set-up costs, need for training and vendor lock-in)
- More worried about possible indirect effects: uncertainty around regulation, liability matters, cybersecurity or trade union response
- Considering their partners and other maritime stakeholders not yet ready for autonomous technologies

Due to limitations in the collected data different market segments involved with this group should be considered carefully. However, shipowners with smaller general cargo ships or offshore vessels are more likely to be found here. Oil tankers can for the large part be considered here as well as it is largely publically viewed in the industry that they should not in the early phase be equipped with e.g. remote control for safety reasons.

RELUCTANT TRADITIONALIST



- Unmanned vessel in the open seas? You have enough to worry about with crew on board *(classification society, expert)*
- Autonomous technologies would make us very dependent of the technology and their suppliers *(small ferry company, technical director)*
- Once in our history we had a vessel on automatic pilot which made a collision at open sea. Very sceptic on the safety issues*. (general cargo shipowner, CEO)*
- Most likely that only little will change as cargo care cannot be automated. Hopefully it will never ever happen. *(general cargo shipowner, operations director)*
- We are in an industry that is driven by short-term market fundamentals rather than finding and applying new ideas on ship design or operation. This slows down the any leaps both in good and bad markets. *(classification society, director)*
- Automation cannot replace the eyes, ears and thinking of an experienced seafarer. Human element is especially for all those sudden changes. *(trade union representative*)

Figure 5 Characterizations of the Reluctant Traditionalist profile, adapted highlight from the data sets.

4.3 Observers

Even if not visible in the media or openly commenting views about autonomous shipping, the Observers form by our preliminary analysis the second largest group of shipping companies at present. They are companies that seek for knowledge and try to learn about the matter but are not yet doing any concrete development actions by themselves. The main attitude with the observers is that it will be a risk in the maritime sector to be among the first ones to introduce something this radically or fundamentally new. Carrying development and investment costs, delays and flaws are a financial risk if the benefits do not follow. For the second movers the risks are lower. Geroski and Markides (2005) provide different business examples of how learning from the first-movers' experiences saves development resources which could be allocated e.g. to sales efforts to gain a large market position. Shipping as an industry with truly global competition is accustomed to a rapidly reacting market environment with low differences in profit margins, which might explain the willingness to observe for many actors. Such companies nevertheless understand that knowledge about technological progress and trends is crucial for their long-term success.

In the simplest form, the Observes group would mean for example that ship-owner's director or expert occasionally attends some industry conferences and stays partly up-to-date about the new technology. On the other hand the Observers could join some projects in a learning purpose and follow several new technologies. However, they do not yet engage in strategic level actions or present themselves publicly to be active with autonomous technologies. Within the company, a single person might later become an innovation champion who promotes new ideas and technologies and in time would start to shift the organization towards taking actions. Many of the Observers operate in international trades where autonomous or remote controlled shipping is not so far possible in terms of international regulations. This factor positions some of the Observers to wait for regulative landscape development before taking action either in the form of system/function level autonomy improvements or by taking a more progressive stand on autonomous ships.

Key characteristics for the Observers group can be listed as follows:

- Has not taken actions towards adopting autonomous technologies but is interested and is observing technological progress and trends by participating in conferences, discussing with system providers and authorities.

- Moderate actions for gaining external knowledge and more external information sources
- Lower top management risk-taking
- Mixed views on the market environment
- Organizational support available in the form of top management attention, information seeking or interest among colleagues but financial resources or other kind of commitment not available, specific expertise missing
- Views on the benefits and challenges of autonomous technologies are mixed: both upsides and downsides are brought up
- More worried about possible indirect effects: uncertainty around regulation, liability matters, cybersecurity or trade union response
- Partners or maritime stakeholders held moderately ready for or supporting autonomous technologies

- The thing is that we don’t want to be early adopters in this ourselves but we follow the development carefully. If it turns out well we’re then ready to go forward *(bulk shipowner, CEO)*
- Everything so far out there are just technological demonstrations. There are so many other elements than technology - the whole commercial and service ecosystem still unfinished which must be sorted out first. *(container feeder agency, local director)*
- For small vessels investment costs are still too high but for larger liners with fixed routing it might work *(general cargo shipowner, operations director)*
- Nobody wants to pay for the development costs of new systems or innovations *(maritime journalist)*

Figure 6 Characterizations of the Observers profile, adapted highlight from the data sets.

4.4 System-specific developers

This group differs from the previous ones by including shipping companies that have in practice taken actions and steps towards utilizing autonomous technologies. The System-specific Developers are interested in the technological trends and new opportunities arising from it but they want to have this development tightly controlled also with options to step back in case needed. Following such frameworks as modularity (Langlois 2002) or systems integration integration (Prencipe et al. 2003) transportation is a classic example of a function accomplished by a technological system composed of sub-systems and their components. A ship can be seen both as a part of a larger service-enabling transportation system and itself as an integrated entity of several different technological and functional systems. Many of the experimentations with autonomous technologies are planned to automate or enhance a single existing ship system. Alternatively, the technological novelties develop into a new sub-system for the existing systems offering a new optional layer of functionalities.

First applications of autonomous technologies are planned to be functioning in a decision-support role for navigational systems. Nevertheless for example automated cargo-handling systems or automated mooring might be selected as system-specific development areas by the System-specific Developers. Often there is a technology provider with which the shipping company partners. Possible added value brought by the system-specific development is mostly considered as a bonus. In principle there is still always an option to revert to a previous (manual) status. More weight in the system-specific development is often given to organizational learning. The organizations engaged into it generally recognize the digitalization trends and autonomous technologies as essential parts of it. The trend is seen and sensed in these organizations as so significant that it cannot be ignored. On the other hand, technology development and innovation projects are simultaneously seen somewhat fuzzy and risky. The answer is often to focus development efforts first into a single system, to learn and gather experience on how an autonomous technology project should be conducted in the digitalization era, and observe and find ways to minimize disturbances to the rest of the organization or other systems and processes in use.

Key characteristics for the System-specific Developers group can be listed as follows:

- Have taken limitedly actions towards adopting autonomous technologies by focusing the development efforts into a single technological system or function and required sub-systems. Supports the technological progress and trends by participating selectively in conferences, discussing with system providers and authorities.

- Moderate actions for gaining external knowledge and more external information sources. Goal of selected development project is to learn about development methods and project execution in case more technologies are adopted.
- Still low risk-taking with top management - option to step back if needed
- Mixed views on market environment
- Organizational support available in the form of technological development in specific fields and for information seeking but capabilities for e.g. organizational innovation or business model transformation still limited.
- Benefits of autonomous technologies are considered mildly greater than their challenges. The perspective is still bounded in the existing operation model and the mode for changes is seen incremental
- Intermediate views on indirect effects: uncertainty around regulation, liability matters, cybersecurity or trade union response. Focusing on a single system also possibly seen as a way to isolate uncontrollable threats also to minimize deviations for the rest of the organization.
- Partners or maritime stakeholders held ready for or supporting autonomous technologies

SYSTEM-SPECIFIC DEVELOPER

- We follow this trend or otherwise we will be left behind others *(offshore supply shipowner, technical director*)
- These tools for navigation support like collision avoidance are some-thing we're constantly looking for but it won't mean that we will start to decrease crew (*ferry company, technical advisor)*
- Pilot service from ashore is one of the most promising aspects for us that is coming next *(general cargo shipowner, technical director)*
- Unexpected events like equipment breakdowns create a need to main-tain a high number of spare parts and as such adding costs. Managing those costs requires flexibility and transparency and there's where Uber or other sharing economy services can be an inspiration. *(bulker shipowner, CEO)*
- Some aspects in safety, following example from the automotive industry, will face changes and improvements to procedures or safety equipment *(general cargo shipowner,*

Figure 7 Characterizations of the System-specific Developers profile, adapted highlight from the data sets.

4.5 Rethinkers

Rethinkers are presently a rare category of shipping companies that have taken an overall stand on utilizing autonomous technologies. They envision those technologies to ignite redefining of company strategies and the industry dominant design operation model overall. Rethinkers raise the ambition and transformative goal above any of the other groups of shipping companies. One force behind the autonomous technologies is the recurrent discussion on flaws and deficiencies in shipping. Although the maritime transport system is able to utilize economies of scale, transparency, flexibility, safety and better overall integration between different transport systems is often demanded. Completely new services and value are expected to be generated for the benefit of the customer, sometimes following the examples from other sectors. Rethinkers see that they themselves must be in the frontier of this development so that those that do not respond to the pressure will face business losses. In contrast to the Observers, the Rethinkers aim for a first-mover advantage in their innovation and business development.

Rethinking is anything but easy. Compared to developing specific systems, the overall rethinking of operations and business models around new technologies becomes a vastly complex task. Technological product innovation is not enough but process and organizational innovations are needed as well to succeed. Rethinkers have a versatile long-term vision of how to redesign their business overall. Also they have enough resources to start planning for different actions. The Rethinkers' group is not necessarily the one that is most rapidly advancing with demonstrations etc. Rather it is the fact that their vision's breadth and depth is far further than e.g. that of System-specific Developers.

Public discussion and opinions from the Rethinkers might have a strong impact on the diffusion of autonomous technologies and discussion around it. According to the agenda construction concept of industrial marketing, so far the autonomous vision has been largely fed by equipment and system providers. Their strategy is to create attention towards new technological opportunities mainly targeted to their customers. So far most of the shipowners and shipping companies have kept quite silent about autonomous technologies in general. However, the kind of shipping companies that fit into the Rethinkers group are likely at some point to start leading and redefining the public discussion them-selves and aim to become opinion leaders. In other words, they start to construct an agenda of their own targeted to cargo owners. When such agendas arise and accumulate changes in the whole maritime sector likely speed up.

Key characteristics for the Rethinkers group can be listed as follows:

- Have started to plan and prepare a broad set of actions towards autonomous operations. One of those actions is company-specific strategy or a roadmap on utilization of autonomous technologies. Still the progress is not among the most rapid ones as details are wanted to be thought out carefully. Aim to be discussion leaders among their customers and maritime stakeholders.

- A lot of actions for gaining external knowledge and establishing information sources. Several system-specific experts and gradually new projects.
- Moderate top management risk-taking. A thrive to formulate the leading vision. Management may be modified so that a Chief Digital Officer or such like is appointed.
- Views on the market environment more steady and price competition is not considered a threat. Strategy involving autonomous technologies seen as a possible way to differentiate.
- Organizational support available gradually for every needs from technological development to organizational and business model innovations. Internal champions are utilized to seek for new growth.
- Benefits of autonomous technologies seen greater than their challenges. Radical changes can be envisioned.
- Indirect effects of regulation, liability, cybersecurity or trade union response are less seen less as obstacles for their organization.
- Confidence that their partners are ready and support the autonomous technologies.

- I am afraid that our industry and authorities are moving too slow in comparison to other means of transport *(general cargo shipowner, operations director)*
- Shipping will start to resemble the airline industry soon *(ship finance banker)*
- Autonomous technologies have potential to accomplish similar revolution as happened with the containerization starting from 50 years ago *(maritime insurance company, consultant)*
- Firstly, we must partner with relevant technology providers. Secondly, we need to form an innovation strategy according to market needs. And thirdly, we need to talk to our stakeholders and beyond to identify what creates and drives value for their ships, ports and businesses *(tug company, business development director)*
- Our industry still has a lot of middlemen and very specialized pieces of information rather than information in common format. A lot of information isn't used well. *(tanker company, operations director)*

Figure 8 Characterizations of the Rethinkers profile, adapted highlight from the data sets.

4.6 New entrants

As all the previous four groups are formed around current shipowners their thinking arises from the current world of shipping. This leads to the different novelties or new thinking still to be anchored in the existing transport system and its actors and equipment, such as ships. More pervasive and radical thinking is likely to be arriving outside of the present shipping and maritime sector. These actors' frame of thinking is different. Instead of looking at improvements of individual elements inside shipping they might see shipping and transport systems in whole as a tool or a building block for new value. They might not have infinite technological capabilities themselves but they know how to partner wisely with start-ups and selected incumbents to execute their plans promptly.

The New entrants and their offerings might be compared to for example what happened to travel agencies or to booking a flight a few years ago. Instead of using an agent or intermediary, online platforms emerged with all the relevant schedule and price information included in the same database which was searchable for any consumer. With improved transparency, the comparison of different alternatives, or finding totally new ones, became much easier than before. In the shipping world a B2B environment with very accustomed ways the principle operating model is still through intermediaries or agents. The shipper, respondent or the carriers all receive only fragments of information. Now consider that the new entrants of this group would adopt the same principles to utilization and management of transport services. Higher transparency and flexibility might lead to higher customer satisfaction and novel services.

Some examples are already recognized. Large retailers like Walmart, Amazon or Alibaba are giving increasing attention to logistics and transportation of their goods. Traditionally they have worked with last mile delivery companies like FedEx and UPS. But due to the complexity of the supply chain networks last mile delivery companies manage to be on time at peak times only on about 90-95 % of the deliveries - not 100 %. This affects the retailers' reputation and customer satisfaction. To counter that, the retailers start to do their own actions also on the "first mile". It has already happened in air transport as retailers have started to lease their own cargo airplanes and partly competing with traditional delivery companies. The first steps have also been witnessed in similar types of initiatives and the rise of control will happen also for shipping and maritime transport. (Coles 2017).

For the New entrants the autonomous ship might not be of value itself but rather a tool in a box to reorganize the transport system under a new logic. Changes in the shipping ecosystem setup might be fostered and triggered by introducing a fleet of autonomous ships operating under new control, management and power structures, interdependencies and supplier structures. It is likely that such new configurations in the ecosystem should involve larger multisectoral consortiums ready and able to drive systemic change.

Key characteristics for the New Entrants group can be listed as follows:

- No visible actions yet but a busy drawing board.
- The visions and plans focus on processes and to the value received by both cargo owner and consumer. Efficiency, transparency and flexibility is highly appreciated. Responses to Industry 4.0. trends of increased automation and data in both manufacturing and transport and cyber physical systems in it.
- Key development area not necessarily the transportation technologies themselves. Primary focus is given to processes of data and information exchange into which transportation technologies like the autonomous ship would be subordinate; the goal of New Entrants is much less on the autonomous ship than for the other groups.

- Very high emphasis on gaining external knowledge and new information. Transportation and maritime know-how possibly outsourced if needed.
- Moderate risk-taking with top management. A thrive to formulate the leading vision. Digital mindset in the whole organization's DNA.
- Large organizational support available. However, there is a risk of not understanding other issues deeply, such as maritime operations
- Benefits of autonomous technologies are considered greater than their challenges. Overall supply chain performance is the main goal.
- Indirect effects of regulation, liability, cybersecurity or trade union response considered less as obstacles for their organization.

- No taxi company invented Uber nor any hotel Airbnb. If shipping is to get truly digitized it needs a revolution and new players. Do we really see the current players inventing autonomous ships, their traffic control and the whole new ecosystem? Rather new technologies, new communications and new people are needed *(satellite communications company, director)*
- If it can happen in the entertainment industry, finance industry and others why not then also shipping? *(classification society, director)*
- We will see more change from ownership-based models to on-demand models everywhere, also in shipping *(scholar in a shipping event)*
- It can be called an Uber or Amazon model or whatever but if someone succeeds to build a digital trading platform for cargo then those who have access to cargo are in a good position. But if you don't have direct access to cargo it might get difficult *(satellite company, business development director)*
- Ex-seafarers rarely have the managerial approach that is needed in this changing world *(ship management company, director)*
- Today the value of companies cannot no longer be measured by their physical assets. Rather it will be about their management and their ability to think creatively and radically *(ship finance banker)*

Figure 9 Characterizations of the New Entrants profile, adapted highlight from the data sets.

Synthesizing this part of the study, we have aimed to draw attention also to the potential users and customers of autonomous technologies and to the markets to which these technologies are aimed to be introduced. Regardless of how advanced and beneficial new technologies are, the potential market transformation is ultimately dependent on shipping companies' ability, willingness and readiness to absorb these innovations. Based on this preliminary analysis framework we argue that the majority of the shipping companies are at present still steps away from the commercial utilization of autonomous ships for numerous independent reasons. The setting here is not by any means static as many industry stakeholders reconsider systematically their standing and role in the transformation. The regulatory environment and authority involvement is gradually becoming more and more favorable for the game-changing phase of the development. The industry will see first commercial solutions in operation within the next two years, which is likely to speed up the transformation pace during the next decades. By profiling current groups among shipping companies in relation to the autonomous shipping development, we want to address the importance of customer experience and value in the transformation and how differently this is currently seen among the potential customers.

5 FUTURE AUTONOMOUS SHIPPING NETWORKS ENVISIONED

5.1 Network visioning - why it matters and how can firms do it

Emerging radical innovation, such as autonomous shipping, leads to uncertainty and instability in the business environment (Low & Johnston, 2009). As businesses strive for radical technological change, they also actively change and recreate the respective business networks. For example, existing business networks face radical changes as it is not clear which actors are needed, what kinds of resources they should hold, and what their value activities will be in future business networks. In this turbulent context, making sense of the future business network requires network visioning, network orchestration and network mobilization capabilities. (Möller & Svahn, 2003.) In the AAWA project, our research focused on facilitating firms' network visioning, as orchestrating and mobilizing the business network would then follow the visioning activities.

Laari-Salmela, Mainela and Puhakka (2015, 125) provide the following explanation of network visioning: "This process is about creating a vision of the network and its potential evolution in order to identify strategic development opportunities: it involves both the actor's perception of the network and the attempts to identify the set of potential relationships." In other words, network visioning should enable firms to better understand which network actors they should seek to interact and network with (i.e. strategize) in order to secure a desirable future position in the business network that they are actively changing through their innovation efforts. Engaging in network visioning activities therefore becomes important for firms who are actively pursuing the future of autonomous shipping:

"If an engine manufacturer pioneers technology that will be central for autonomous shipping, will shipowners adopt it? The same goes for navigation. So co-ordinating the "complexity and inter-relationships in an essentially self-adapting system" will be the key to adopting autonomous innovation." (Watson 2016)

Although network visioning is recognised as a significant strategic activity in the business networks literature, no managerial tools have been introduced in the literature for facilitating the process in firms. As network visioning entails a future outlook, we thus turned to futures research and developed a methodology combining methods from business network research and futures research. The resulting Network Visioning Workshops were conducted in 2016 and 2017 with five companies contributing into the project. The companies represented various roles in the maritime industry such as ship design, shipyard, and different system providers of propulsion and automation, cargo handling and navigational support. Each of them are actively involved in driving the autonomous shipping transition forward. The workshop participants represented different company functions usually involving at least people from R&D and innovation, engineering, sales and marketing functions. This was done in order to enrich the resulting vision and to facilitate its acceptance across the company. The number of participants for the workshops varied between 6-12 participants and consisted of different age groups and . The starting point for each workshop was the assumption that in 2025, autonomous technologies are in commercial use in the Baltic Sea region in the general cargo sector, and the ships operate autonomously or under remote control when necessary.

In brief, the workshops were threefold. First, the futures triangle describes the firm’s desired future vision of autonomous shipping (pull of the future), the features in today’s business landscape that could help them achieve the desired vision (push of the present), and the historical aspects that may inhibit the vision from becoming a reality (weight of history). This tool provided each firm a desirable goal to work towards. Second, backcasting visualises the transition to the desired future by first placing the workshop participants in the desired future and then asking *what* changes have occurred and *how* those changes have been achieved. The outcome was an outline of events and milestones that need to happen for the desired vision to realise. About backcasting Vergragt and Quist (2011) provide overview and origins for it as a tool to illustrate a desired future in a normative setting by examining the agendas, strategies and pathways related to the context. Lastly, the network picture answers *who* are needed in the desired future vision (business and societal actors), how the actors are linked to each other (what types of relationships exist between them), and how influential or powerful the actors are in terms of the functioning of the future business network (based on their resources). Each firm was then able to establish which business role(s) it could occupy in the network, and see which actors it needs to begin to interact with today if it wishes to occupy a certain role in the future.

Each of the workshops resulted in a firm-specific desired vision of autonomous shipping in 2025. In this report, the results are next discussed in an integrated manner utilising the *PESTE -framework* (Politics, Economy, Society, Technology and Environment). It is important to note however, that the research did not aim at predicting the future, but rather the following narrative represents one possible scenario of the autonomous shipping future.

5.2 Pull of the future - A vision of autonomous shipping in 2025

Figure 10 summarises the main aspects of the integrated vision of autonomous shipping in 2025 as described by the participating developer companies.

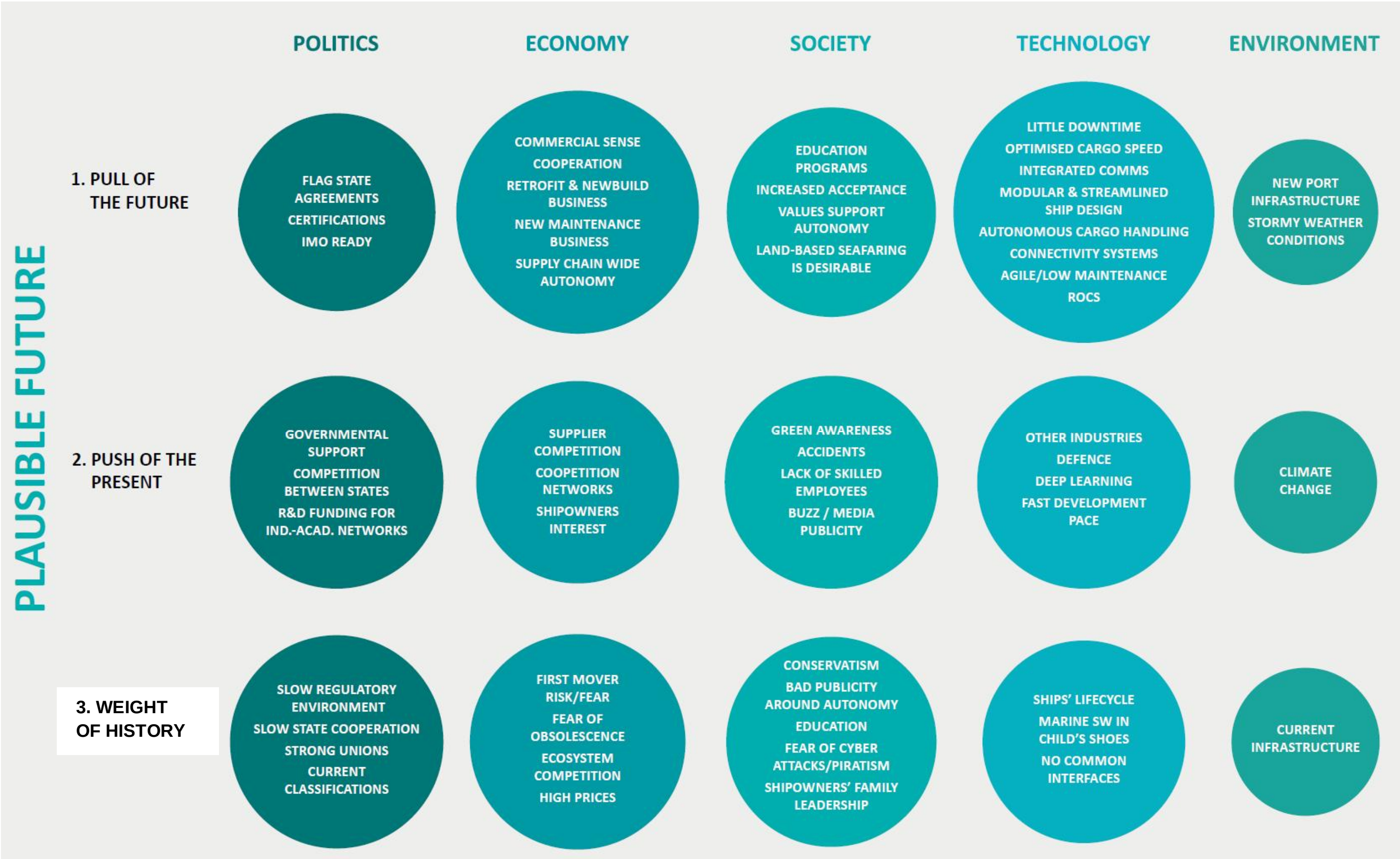


Figure 10 Integration of plausible future triangles of the company visions for autonomous shipping in 2025

Politics: By 2025, the Baltic flag states have together agreed to allow autonomous and remote controlled ships to sail on their waters. Various types of permission mechanisms have also been put into place by regulatory bodies to ensure safety. These include standards and certifications for autonomous ship operations as well as qualification approvals for autonomous systems and the related hardware and connectivity technologies. In addition, standardised interfaces have been introduced for technological solutions. While ensuring safety, this also means that small suppliers are able to work with multiple larger system suppliers as opposed to being able to offer their services to only one larger firm, thus increasing their opportunities for growth. These mechanisms are reinforced by classification societies.

Economy: The starting point here is that autonomous shipping is an economically feasible business area in relation to manned shipping. It is also recognised that the biggest benefits can be derived from introducing autonomy throughout the entire supply chain, which is to be optimised according to the cargo owner's needs.

Related to the changes introduced in the regulatory environment, in 2025 we are seeing close cooperation between system suppliers and various societal actors to ensure the benefits of autonomous shipping for commercial actors as well as the society. The industry-wide standards discussed above also mean that the shipowner is not ”married” to a specific system supplier, but is able to replace one provider's systems with those of another. While this may not be the ideal situation for suppliers, it is considered to be in the customer's interests.

In general, there are two possible business streams for commercial actors. First, they can provide retrofit solutions to manned ships which make use of the autonomous technologies developed and matured during the transition period. These are supportive systems for ship navigation and operation, which can be utilised in all ship types, and provide business already in the shorter term. The second stream are newbuilds that are autonomous and remote control operation ready, and thus represent longer term business solutions.

In addition, autonomous shipping has created new business and competition in the industry in the form of agile maintenance and support services for ships and land-based remote operation centres. These services increase in importance as the number of crew onboard decreases. Also, modular system installations make maintenance and repair quicker and easier when the parts needing repair can be quickly replaced with functioning ones and repaired elsewhere. Thus, system suppliers are able to offer lifecycle service

Society: Overall, the society views the use of autonomous solutions positively due to their development in various transportation and industrial sectors. Autonomous operations are seen as reliable and worthwhile as well as more environmentally friendly than manned operations. In the shipping industry, information transparency and awareness of the impact that purchasing can have on the environment are important values, which support the use of autonomous solutions. These values are especially carried by a new generation of seafarers who have gone through new education programs specifically aimed at training autonomous ship personnel. In addition to education programs, certifications for autonomous ship personnel have also been introduced, and only certified people are allowed to perform maintenance tasks on them.

Technology: In 2025, communication between the factory, port, and ship operates in a manner that allows for the rotational speed of cargo to be optimised to the cargo owner's needs. For shipping, the benefits of this include minimised ship downtime, their higher utilization rate, and in general higher system reliability. These capabilities are supported by the following technological developments which are seen in operation by 2025:

- Ship design: streamlined design and modular system installations to decrease maintenance needs. In addition, the use of electricity means that the damage-prone moving parts related to the use of oil or diesel can be removed, thus also reducing maintenance needs
- Remote Operation Centres: Finland is widely recognized as a knowledge hub regarding ROC operation
- Sensor fusion solutions and AI
- Connectivity systems: in addition to new generation satellites, reliable connectivity is supported closer to shore by 5G, 4G Mesh Network, as well as Digital Dolphins (i.e. buoys) and drones functioning as access points
- A separate network for autonomous systems (i.e. separate from the internet to prevent cyber attacks)
- Autonomous cargo loading and unloading at ports
- Modular cargo transportation units
- Real-time cargo traceability
- Autonomous cars and trucks are in use in the supply chain

Environment: Considering the conditions in 2025, port infrastructure seamlessly supports the functioning of the new agile ship maintenance needs. Some ports have introduced separate terminals for autonomous ships to allow for autonomous mooring but also the required levels of operational. Autonomous cargo handling solutions also mean that there are very few people working at the port.

In general, due to climate change we are witnessing increasingly stormy weather conditions, which put more pressure on the shipping industry to shift people to land-based jobs.

5.3 Push of the present - what drives us towards the desired future

Politics: Today, we are witnessing autonomous shipping development initiatives in a number of countries around the world. These efforts are actively supported by their respective governments through e.g. testing permissions and providing R&D funding for industry-academia innovation networks. During the workshops, this was often described as a competition or race to autonomy between countries. The Nordic countries were seen to be at the forefront of the race, with Finland leading the way, emphasising the importance of staying ahead of China in particular. In addition, it was recognised that the first regulatory and classification steps taken towards allowing autonomous shipping to become a reality are encouraging system suppliers to continue their efforts. Local authorities, classification societies, and the IMO were given credit here.

Economy: Competition between critical system providers in particular was also seen as a major driving force for autonomous shipping, as large players are actively pushing the related technological development forward. However, competition and cooperation were considered to coexist in the form of various coopetition networks aiming at pushing autonomous shipping development forward. Also, increased interest from shipowners and cargo owners towards the use of autonomous technologies was deemed a powerful force in legitimising the development efforts as something worth pursuing by suppliers. In general, an Industry 4.0 way of thinking was seen to prevail in the shipping industry as well as the overall supply chain. This was characterised as an understanding for the need for information sharing and transparency in this era of information and automation, which would then translate into more service offerings based on data.

Society: Changing attitudes in the society were also discussed as drivers for autonomous shipping. Overall, environmentally sustainable solutions are increasingly valued more not only in the shipping industry but the society as a whole, which supports the acceptance of autonomous solutions in other industries as well. Workshop participants often mentioned a general buzz around autonomy in societal discussion, which spills over to the shipping industry. Positive medial publicity was deemed as a contributing factor in creating the buzz.

In terms of attitudes in the shipping industry, accidents at sea were seen as a major factor in moving thinking and acceptance towards the use of autonomous solutions, as they are seen to increase safety at sea. In particular accidents caused by human factors were thought to provide support for the introduction of autonomy in shipping. Also, attitudes were thought to be moving towards a lack of interest for a life at sea; especially the upcoming generation of seafarers were deemed to show more interest for land-based positions. Already today, a lack of skilled employees in the industry was seen to support the increased utilisation of autonomous technologies instead. However, while attitudes towards autonomy might be changing in the industry, the importance of human skill is not to be overlooked as we seek for optimum balance in the human-technology cooperation:

"I have worked for more than 45 years in a shipping company, which had always been in the forefront of technology. I see the positive result of moving forward in the right pace, not too fast, not too slow. We must plan our future, but smart ships and smart ports should not create dumb people. Shipping is a team cooperating in handling the problems of the trade, therefore we have to adapt to the solitude of the lone ship in a rough sea". Director at a ship management company (from media articles, see chapter 3.2)

Technology: The autonomous technologies development that is taking place particularly in other transportation industries was seen to significantly push the respective development forward in the shipping industry. Similarly, applications developed in the defence sector was considered to have the same effect. In general, deep learning solutions developed today were discussed as a prerequisite for further development of autonomous technologies, and overall the fast development pace of the relevant technologies was recognised to support the achievement of the desired future vision by 2025.

Environment: While climate change was discussed mostly under the pull of the future, it was also recognised as a pushing force already today as we begin to witness increasingly more demanding weather conditions at sea.

5.4 Weight of history - what slows us down

Politics: While workshop participants recognised that advancements had been made in the political realm to allow autonomous shipping in local and international waters, these were considered as baby steps, and the regulatory environment was nevertheless described as slow to change and posing unnecessary limitations to innovation. For example, current classifications were not seen to support new solutions built around autonomy. In addition, the possibility was discussed that flag states may have differing interests in the IMO, which slows down the regulatory development at that level. Also, although support from individual states was often commended, cooperation between different flag states was seen to take place too slowly, as it is a necessity for extending autonomous shipping beyond the waters of just one state. Finally, the strong position of seafarers' unions especially in the Nordic countries was often discussed as possibly slowing down the transition to autonomous shipping.

Economy: Shipowners were frequently discussed as playing a central role in the transition to autonomous shipping. The issues here included their lack of funding for innovative initiatives as well as general first mover risk or fear. The currently high prices for system components were thought to cause disinterest in investing in the new technologies, especially as first movers. Beyond shipowners, some players in the shipping industry were thought to potentially attempt to slow the development down in fear of becoming obsolete in the future, e.g. shipping brokers/agents or ship managers.

System suppliers were also seen to experience barriers to innovation. First, gaining marine approval for technologies was recognised as a long and expensive process, which means that suppliers coming from outside of the shipping industry may be disencouraged to bring their innovations to the shipping market. Second, it was envisaged that competition between so called innovation ecosystems may lead to a situation where autonomous solutions developed in different ecosystems (i.e. solutions competing for the dominant design) are incompatible. This situation would be harmful in particular for small suppliers looking to scale their business to different ecosystems.

Society: One of the most frequently mentioned issues weighing down autonomous development was the shipping industry being characterized as conservative. E.g. slow or old operating processes and careful investment behaviour were included in this characterization. Such behaviour or attitudes were further thought to go hand in hand with shipowners' traditionally family-led management. Thus, a change in the management generation was deemed a necessary precondition to renew shipowners' attitudes. Furthermore, it was thought that concerns for cyber security and piratism slow down the willingness for data sharing between different shipping players. This issue is not helped by bad publicity around autonomy in other transportation sectors, most often reported accidents involving an autonomous car, which also has a negative impact on how much people trust machines.

Autonomy was seen to bring with it uncertainty and confusion in terms of changing business models, which stands in contrast to how business operates today; the shipping industry has operated in the same way for a long time, with clear business roles between different players. This stability is now being threatened by the potential of autonomous shipping. Also based on the same stability, seafarers' education programs have not been geared towards autonomy, but rather to uphold the system organised around manned operations.

Technology: In terms of technology, the long lifecycle of ships operating today means that the transition to autonomous shipping is slowed down by the existence of an ageing but still functional fleet. Also, maritime software development was described as being in very early and emerging phase. More specifically, the lack of a software development culture in the shipping industry was seen to lead to a situation where there are no supportive processes for this development. This was also seen as being manifested by having no agreement on common interfaces.

Environment: As for issues in the environment, the current transportation and port infrastructure was thought of as unsupportive of autonomy. Changing this would require large investment from governments and commercial actors alike, which was seen to significantly slow down the innovation activities of system suppliers pursuing technological development.

5.5 A path towards the vision

5.5.1 What changes are needed and how could they be achieved?

Placing the workshop participants in their desired 2025 vision, during the backcasting analysis they first focused on the changes that have taken place since 2016/2017 to bring about the 2025 vision. On the one hand, this *what* question covers changes to the issues discussed in the "weight of history", i.e. they represent the problems that need to be overcome if the desired future is to be created. On the other hand, the *what* question also covers reinforcing and supporting the aspects recognised in the "push of the present".

The *what* question goes hand in hand with thinking about *how* the changes have been achieved by 2025. Therefore, the participants then placed various actions and activities on the backcasting timeline, which included e.g. the following:

- Formation of strategic partnerships
- Establishing development projects (industry or industry-academia)
- Technology pilots
- Entry of new types of maritime or logistics companies
- Communication in the media
- Lobbying regulatory bodies
- Establishing new education programs for future seafarers
- Support from the governments of the Baltic States in the form of agreements to allow autonomous & RC ships to sail in their waters

Next, the critical events on the timeline that were most often brought up during the workshops are briefly described. Company specific actions and activities are omitted from this report to preserve confidentiality. As backcasting "looks backwards" from the 2025 vision, the events are reported in past tense.

Figure 11 visualizes the backcasting exercise from 2025 backwards.

2018: In partnership with their customers, critical equipment providers received permissions from their Baltic flagstates and a classification society to build a proof-of-concept to demonstrate autonomous navigation. Meanwhile, commercial assistive situational awareness systems begun to be installed on all types of ships, and the first electric ferry with built-in autonomous readiness begun to operate on the Finnish coast.

2018 also saw an increase in different types of cooperative advances, which were widely reported in the media, e.g. system suppliers begun working with the future generation of seafarers for product development as well as with cargo handling providers and communications providers to work on system integration and communication hierarchies. Having witnessed lobbying especially from system suppliers, regulatory discussions between some of the Baltic government officials [most likely first between Finland, Sweden, Estonia and Denmark/Germany] also started with the lead of Trafi and the Finnish Ministry of Transport and Communications.

2019: In 2019, shipowners started to publicly announce their involvement in competing autonomous development "ecosystems". These ecosystems were led by different large critical system providers (e.g. by Rolls-Royce, Kongsberg, Wärtsilä, ABB) and backed up by their respective states (e.g. Finland and Norway) and a specific classification society (e.g. Lloyd's and DNV GL). While these ecosystems were competing, there was cooperation between them to settle "the rules of the game" so that e.g. a remote operation centre (ROC) could offer services for vessels developed within different ecosystems.We also started to see more and more news from Chinese autonomous development projects taking place.

The electric ferry on the Finnish coast was now operating autonomously, albeit not unmanned, and in general, frivolous testing of various autonomous technologies continued to take place worldwide. Also, new education programs were established for autonomous shipping to cover the need for more IT-related skills and a service-oriented mindset in the future generation of seafarers and marine engineers.

2020: The system integrations and communications hierarchies were completed by 2020, classification societies had finalised their requirements for autonomous and RC vessels, and the Baltic flag states had arrived at contractual arrangements to allow the vessels to sail on their waters. News headlines reported on the first remote operation centre being built in Turku, autonomous technologies having prevented collisions at sea, and crucially, the first autonomous navigation POCs being rolled out successfully.

The beginning of the 20's also saw more severe weather conditions, which contributed to a major accident involving human errors and resulting in loss of life and an environmental disaster. The accident was widely covered in international media, and resulted in more heated discussion around the need to significantly reduce crew numbers at sea for increased safety. It also led to more demand for safety solutions in the commercial shipping sector, which further pushed the industry towards increased levels of automation and heavier investment in R&D activities from solution providers and shipowners alike.

2021: After the successful POCs, the first orders to build commercial autonomous & RC vessels were placed, which at the same time received insurance approvals. Those placing the order(s) were not necessarily the same shipowners who had engaged in retrofit testing in earlier years. The first orders significantly boosted the pace of development both technologically and socially. The rest of the Baltic states also jumped onboard, and infrastructure development was started in ports and shipping channels between the states.

2022: In Finland, ferries in the archipelago reached autonomous capabilities enabling more efficient traffic. This resulted in positive migration to the archipelago, improving its economic outlook. Overall, the shipping industry begun to witness a generational change in leadership, thus leaving old attitudes in history and quickly speeding up the industry's transition to autonomous shipping.

Changing weather conditions also drew public attention as the Gulf of Bothnia did not freeze over during the winter. Headlines drew attention to the relationship between autonomous & RC vessels and worsening sea conditions, promoting the vessels as safer and more reliable.

2023: Following the successful POC in 2020 and order placement in 2021, the first commercial newbuild autonomous & RC ship was delivered in 2023 and was quickly followed by a number of others. At the same time, the first highly educated seafarers and marine engineers specialising in autonomous shipping graduated and entered the job market.

2024: Throughout the time period from 2017, various connectivity technologies had developed towards more reliable and secure solutions. Consequently, by 2024 the price of data transfer had dropped significantly. Also, ship-port IoT solutions were operational, and port and pilotage interfaces had been agreed upon. As 2025 approached, the first commercial autonomous & RC vessel begun to operate between Helsinki and Tallinn.

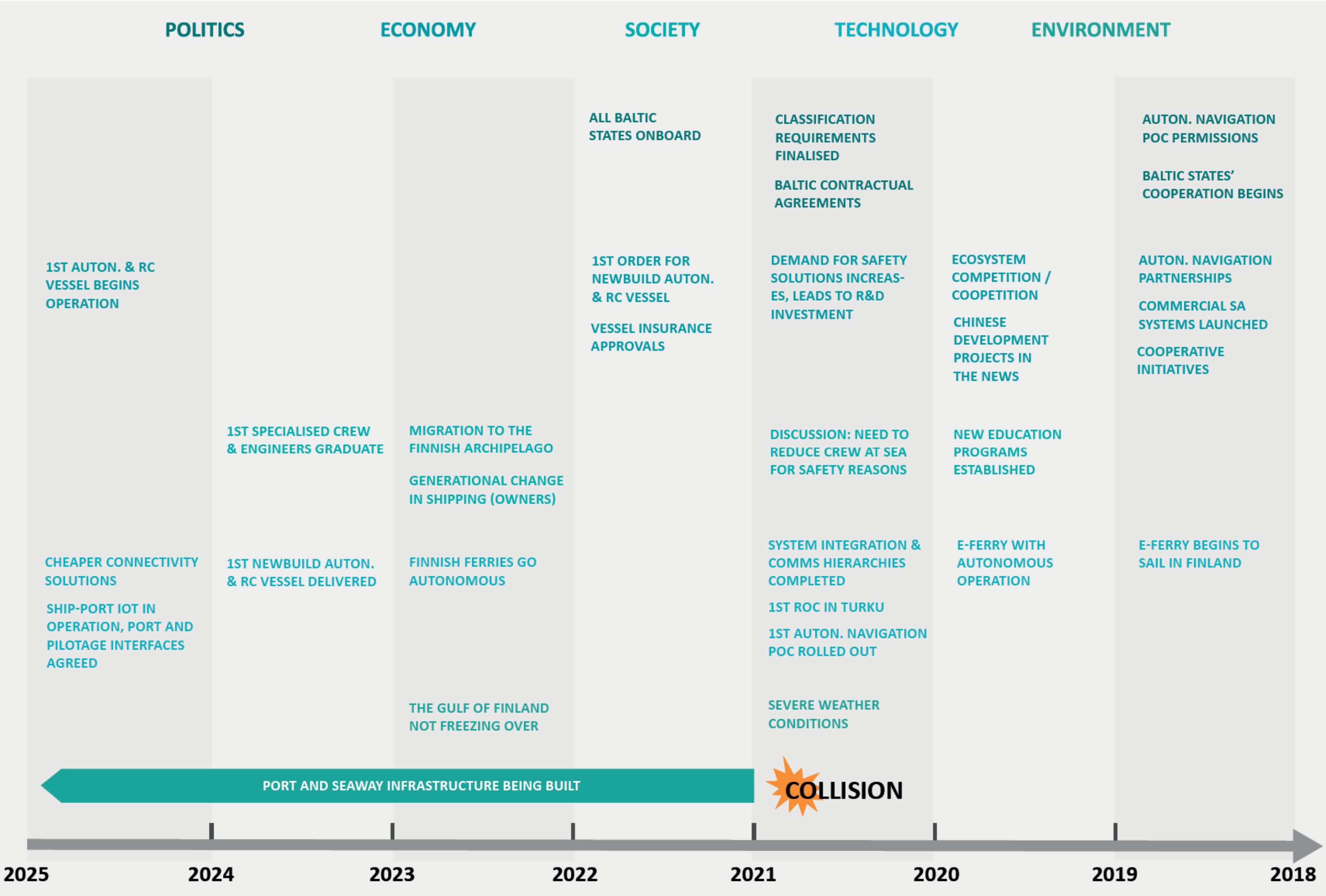


Figure 11 Summary of the integrated backcasting findings with a reversed timeline on what is in 2025 remembered to have happen

5.5.2 WHO are needed in the vision?

Autonomous shipping is set to change the way the shipping industry functions today. This may mean that the market will see current business roles reforming, new roles emerging, and some roles becoming obsolete. By actively driving the autonomous shipping transition forwards, innovating firms are also repositioning themselves in different business roles and as such creating the future business network. Coles (2017) recognizes this phenomenon in the shipping market:

"We could see smaller ships for the local routes and some larger ships for the longer haul. This will probably evolve based on what the shipping innovators demand and as they become the main players. Even outside the container sector, we will see dramatic changes as the maritime industry seeks to remain competitive."

To make sense of the possible future roles, in the Network Visioning Workshops the innovating firms thus needed to address the question of *who* is needed in their desired future vision of autonomous shipping. For this purpose, each firm created a network picture, which is a subjective image of their surrounding business network in their desired future vision of autonomous shipping in 2025. These images include information on which business and societal actors are involved, in what ways they are connected to each other, and how much relative power they hold in the functioning of the future shipping market.

Next, the changing business roles, new business roles, obsolete business roles, and societal roles are discussed according to the workshop results. Also, power distribution in the integrated 2025 autonomous shipping vision is briefly described.

Changing business roles: While a large number of actors in the shipping industry appeared in the firm-specific network pictures to perform the same business roles as today, some roles were seen as notably different in 2025.

- The shipowner can be a financier or a collection of them, and the shipowner as understood today could become a shipping company who leases the ships from the shipowner and makes money on the shipments.
- Ship management services are to become more agile, predictive and land-based. The ship manager takes care of the basic maintenance needs of the ship, and its customer is the shipping company. This means that in terms of autonomous & RC ships, the ship management company's business is based on more technical management as opposed to crew management services.
- Ship maintenance services could be based on a power-by-the-hour business model with modular system installations, and are provided by ship system suppliers to the ship management company.

- The ship system supplier role would be extended to autonomous system supplier, i.e. they offer products and services with software (autonomous navigation) and hardware (critical equipment) components. Their customer is the shipyard who serves the shipowner.
- The shipyard could occupy a data integrator role, providing new lifecycle analysis services to shipowners and selling its auxiliary suppliers access to the integrated shipowner's data.
- Cargo owner could merge with a 3PL/cargo forwarder and shipowner/ship operator to form one large actor, e.g. Amazon could become an overarching logistics actor like this. The Yara Birkeland case also exhibits signs of this type of business role mergence in the general cargo sector to remove 3rd party middlemen.

New business roles: The era of autonomous and remote controlled shipping was also envisioned to bring with it new types of business roles due to the remote control function and data integration needs.

- *ROC operator* is responsible for the remote operation and supervision of the vessels. Its customer is the shipping company whose business relies upon the smooth operation of this service. To ensure the safe, secure and economic operation of the shipping company's vessels, the ROC operator also works closely with the ship management company. Large shipping companies could operate their own ROCs and purchase a backup service from the autonomous system supplier, while small shipping companies would outsource the service completely. When considering the business roles in the shipping market today, the ROC operator's role could be occupied by today's critical system suppliers, or by ship management companies in a bid to move their crew management services onshore.
- *ROC integrator* provides the ROC operator the shore-based ROC equipment
- *ROC system provider* provides the shipowner the ROC equipment installed on vessels. The ROC operator, integrator and system provider roles are complementary and as such they could be occupied by the same company.
- *Digital marketplace provider* (or logistics operator) runs a marketplace in the autonomous supply chain to optimise the rotational speed of cargo to the cargo owner's needs, minimize vessel downtime, maximise the transportation capacity both at sea and on land, and handle the cargo-related paperwork in a digital format. In the supply chain, the marketplace provider pays transportation fees to the land transportation provider and the shipping company, and in return receives cargo transportation fees from the factory/cargo owner.

- *Data integrator* plays a coordinating role in the transportation system by integrating data flows to provide a link in optimizing the cargo owner's business processes with those of the end customer's. The data integrator receives information input from various business and societal actors throughout the supply chain ranging from the cargo owner, land and sea transportation actors, shipbuilder and ship management companies to the flag state and insurance company. This information/data regarding transportation and customer needs is required by the digital marketplace provider to run the marketplace, and therefore it is also possible for these two roles to be performed by the same company.

Obsolete business roles:

- In the workshops, various types of middlemen in the shipping market and the wider supply chain were often mentioned as roles that would no longer be required in the era of autonomous shipping. These included services provided by actors such as *shipping agents, brokers, or 3rd party logistics (3PL) providers*. In particular the entry of digital marketplaces was seen to replace the need for these types of actors in the market. Thus, they were seen to either disappear altogether, merge with other actors or pursue the role of a marketplace provider.
- *Crew management* services as provided by ship management companies today were not thought to be needed in the same capacity in 2025 in autonomous & RC vessels. However, as noted earlier these services could be provided by ship managers as land-based services.

Societal roles:

Different kinds of societal actors play a role in the autonomous shipping transition and the functioning of the autonomous & RC shipping market. The workshop participants typically addressed the following societal roles:

- *Public authorities* were most often discussed in connection to roles regarding the regulatory environment and R&D funding. These actors ranged from country-specific local authorities to industry-related authorities and international regulatory bodies, e.g. the Finnish Transport Safety Agency (Trafi), the Finnish Ministry of Transport and Communication (LVM), the International Maritime Organization (IMO), the EU, the Baltic flagstates, and port authorities and their related Vessel Traffic Management (VTM)
- The *media* was recognised in particular for its role in shaping public opinion on autonomous shipping and in general the employment of autonomous solutions in different areas of the society.
- *Research and education institutions* were seen to provide actors in the shipping industry with knowledge and capable personnel. Universities were often closely connected with innovating companies through R&D

projects and educating maritime engineers, and occupational maritime education providers were connected with the ROC operator or ship management through crew/seafarers' education.

- *Trade unions* were seen to either play a role in advancing the autonomous shipping transition into a direction that is favourable to the future generation of seafarers by working closely with innovating companies, or they were seen to act in a disturbing role towards the transition.

Power distribution: As Watson (2016) puts it about a complex adaptive system like shipping, "the shipowners are the dominant class of actors because the ecosystem exists to serve them". This illustrates traditional thinking about power distribution in the shipping industry with shipowners occupying the dominant position in the functioning of the market. However, as discussed earlier, as the industry transitions towards autonomous shipping and its "borders" extend to the supply chain, traditional business roles change (including the shipowner's), and new players enter the market with a different set of resources and capabilities. This also influences the way power is distributed in the reorganised future network. Therefore, power in the 2025 autonomous shipping network was discussed in terms of the resources held by different actors, including financial resources, materials, infrastructure, technology, people, knowledge, legal authority, and network relationships.

Overall, the most power was thought to reside in actors who held integrative roles in terms of data, e.g. the digital marketplace provider (or logistics operator) or data integrator, whose power was based on knowledge and network relationships. Interestingly, these powerful actors do not yet exist in today's shipping network in the envisioned capacity. Furthermore, workshop participants saw their own companies as either occupying roles involving data integration from a number of sources in the network, or as working closely with such actors.

Secondly, the factory or cargo owner were recognised as powerful actors when considering that the autonomous transportation system would be organised around the cargo owner's needs, i.e. to optimise the rotational speed of cargo. They are also able to choose which marketplace to use, thus influencing which marketplace eventually wins the dominant position. The end customer (e.g. the consumer) was also thought to hold moderate power when it came down to accepting or even demanding the use of autonomous solutions in the supply chain.

Third, the shipowner in its changing form as a collection of financiers was thought to be a powerful actor, as its financial resources would be needed to employ the autonomous solutions at sea in large volumes. Although not all workshop participants thought that the shipowner's role would change much in comparison to today, the shipowner was still placed in a powerful position in the network for the same reasons.

Fourth, in some visions relatively high power was given to actors who have the power to coordinate or regulate other actors' activities. These included classification societies, insurance companies and various public authorities.

Finally, it is worth noting that the shipbuilding sector in general was not seen to hold much power when considering the whole supply chain. However, within this sector there were differing views as to which actor holds the most power. For some, the autonomous system supplier was deemed to have the most power due to its close cooperation with a number of other actors in the network (e.g. communications providers, ship maintenance provider, shipyard, ship designer, component suppliers, ports). These other actors were seen as part of the network, but they were not thought to hold much power in terms of the functioning of the shipping market. Thus, they were also not considered to be as interested to drive the autonomous shipping transition forwards. The other view of power distribution within shipbuilding saw the shipyard as holding the most power due to its data integration capabilities between various auxiliary equipment providers, IT suppliers and shipowners, resulting in critical knowledge about the ship's operation.

6 CONCLUSIONS

This report has compiled main topics and insights from several analyses during the AAWA -project and provided an overall onlooker synthesis of company activities and public discussion during the project. It covers thematic fields where University of Turku/School of Economics has participated during the project but not all fields covered by the whole project consortium. In the report a theoretical background from innovation studies and business network research formed the basis for understanding what the transition towards autonomous shipping is about from a business perspective. Also the report included a brief picture of key development milestones towards autonomous ship's idea in history as well as more detailed events and highlights since 2012. Additionally, the report included results of Network Visioning workshops where the creators of maritime autonomy, i.e. active system providers, each created their future visions of where autonomous technologies would lead them and the maritime industry as a whole. A summary of the workshops' findings was presented to provide an overall understanding of how the future of autonomous shipping is envisioned by those companies at this point in late 2017.

We sum up four points on the maritime sector's transition towards a more digitalized future. Firstly, a number of existing theoretical frameworks fit well to explain the maritime autonomy phenomenon and the related discussion. In particular, sociotechnical transition can be taken as an overarching theory into which various events and dimensions can be positioned. Studies and concepts from business networks and industrial marketing research remind us that creating and sharing visions is an important tool that is needed in complex B2B environments and specifically in the context of emerging technologies. This helps us to also understand that even though some of the visions might not sound feasible or realistic, the visions are nevertheless needed to trigger changes to materialize. Overall, from a theoretical perspective the ideas around maritime autonomy are not something completely new or unique but as a phenomenon it can be pieced together from existing research.

Secondly, when looking at the actualized development and facts so far it can be noted that automation in maritime transportation has grown steadily over the decades while simultaneously ship crew size has continued to decrease. In that sense digitalization and autonomization can be seen as a continuum for the same development process. However it can also be argued that the scale and scope of the buzz and discussions on the topic show that perhaps there is something more underlying the phenomenon. Since the containerization the maritime sector has not seen major systemic changes. Something like it would be expected by many for the sector. Our main observation is that very many shipowners and shipping companies are still largely passive or cautious towards digitalization and especially autonomous technologies. One evidence related to this is the scarcity of public standpoints and industry-level statements about the technologies by shipowners, especially until very recently. Most of the discussion has been fed by the equipment and system providers. Partly because of this, the profiling of shipping companies was less detailed as planned. By expanding the analysis to cover more heterogeneous and more general data five profiles of shipping companies could be formulated. Regardless of missing consistent data, we can conclude that the Reluctant Traditionalists are perhaps the largest group among the shipowners at the moment. This would logically imply that it could still take decades for the whole industry to adapt to new technologies, despite the growing number of earlier adopters. The number of Observers and System-specific Developers is fast growing. In our classification, the Rethinkers and New entrants clearly act as vision builders and discussion leaders and will likely trigger whole industry-level changes.

Thirdly, one recurring observation from the event timeline is that the cargo owners seem to increasingly take part in autonomous technology development. This has happened very recently. As the number of active shipping companies involved is still growing very slowly it is likely that the pressure for changes will mostly come from cargo owners. Although the current shipping and transportation systems are able to utilize economies of scale well, some cargo owners demand increasingly more in the digital era. As described with the New Entrants group, some cargo owners want to subordinate deliveries and logistics to their detailed control to take care of customer satisfaction and experience by any means they can. Signals now show that this will have an effect on the maritime sector. It also means that the direction of focus and development efforts is shifting from ships and their equipment to the supply chain. The benefits of autonomy are seen as more significant when adopted into entire supply chains. A single autonomous ship alone is not necessarily an interesting business case, but the integration of additional artefacts, processes and organizational changes together will start to catch larger value.

While we recognize that cargo owners are able to significantly impact the emerging transition, the shipping companies should not be forgotten as the full reaction from them might just come slightly later in the process. An example from the Finnish shipping history illustrates that in the 1950s Finnish companies operating trucks and buses became highly interested in pursuing a modern ro-ro ferry connection from Finland to Sweden. Until then conventional vessels with cranes were used in the trade lane which meaning slow loading and unloading with numerous cargo damages. Inspiration came from Norway and Denmark who had built in the 1930s ferries with car decks enabling faster port operations. At first, traditional shipping companies operating steam ships refused to order ro-ro vessels despite their customer wishes, claiming that the utilization rate of new vessels would be too low. In response, truck and bus companies begun planning to form a joint venture which would order modern ro-ro ferries. Shipping companies in turn started to play a media game and publicly implied that they will also order ro-ro vessels. This scared some parties away from the truck and bus company consortium and the initiative stopped. After that it took still another two years before first ro-ro ferry order really was placed for a Finnish shipowner and still four more years before the vessel was completed. (Riutta 2005.) In this case, the counter-reaction from the shipping companies diverted the development to their control. Similarly, we can expect that the more cargo owners enter the autonomous ship development the more shipping companies will have to react somehow to the situation, especially if large global manufacturers, distributors and retailers make substantial moves.

Fourthly, the Network Visioning workshops signal ways and forms in which autonomous shipping could create new kind of business value. What the AAWA project itself and most of the events in the constructed timeline showcase is the ongoing technological search within different systems and niche accumulation of applications for the technologies. Especially equipment and system providers engage in different technological demonstrations in the search for solutions that would be applicable in the markets. Connectivity, sensors, navigation, automation, decision support etc. are topical focus areas in a ship now under development with many of the companies. Together these form a physical layer of autonomous shipping including all the systems, components and functions that are now rapidly progressing.

As mentioned earlier, autonomous development is more and more about supply chains. Between an order-placing consumer and order-fulfilling producer there are complex networks of suppliers, carriers, agents and other intermediaries. A significant enabler in this picture, also for autonomous ships and their technologies, would be a new digital marketplace - a platform of data that would partly streamline the processes at large in those networks. The ability to access rich information flows and data on delivery times, routes, stocks, capacity levels and related changes to the same platform would allow actors both at the consumer and producer ends to make nearly optimal business choices in every situation. This altogether could be called the information layer of autonomous shipping.

One general conclusion to be made is that the physical layer is already progressing well. Many equipment and system providers are developing their own future products and gathering up partners. But it is perhaps the information layer that still remains as an unsolved key for the transformation. Besides multinationals, also numerous start-ups have emerged during the past years to solve the puzzle but still without global systemic level breakthroughs. The highly interesting question is what kind of synergies those two layers will have together.

The Network Visioning workshops highlighted that an autonomous supply chain using autonomous transports and functions would be able to react faster and more precisely to changes interpreted from various data flows. Improved connectivity could create transparency forming a basis for new services. Also improved safety and reliability would reduce deviations and interruptions in deliveries and overall supply chain performance.

On-going activities have to some extent a tone of technological push as many equipment providers and technology developers are now pouring their ideas to their customers or stakeholders. Deeper and broader customer understanding is needed to really understand user needs and how value should be created. The discussed theories indicate that those things are coming too. This industrial behaviour has logically started from the vision and technology. Following Möller and Rajala’s (2007) terminology we are now witnessing an emerging business field. Inside of it there are networks forming for different purposes. Most initiatives witnessed in the timeline are so called application nets that represent technological and market search for such combinations that would receive a positive market response. As the feedback from these demonstrations starts to aggregate the next step will be the formation of dominant design networks. Then, the valuable question is which actors from both the physical and information layers will be involved to form the dominant design for the autonomous shipping system?

The Nordic countries and Finland in particular are well positioned to host such actors that could become key players in such a dominant design network. Maritime equipment and system providers have placed autonomous shipping and related technologies high on their development agenda, and Finland is a major post for many of them. Ecosystem for the autonomous shipping has started to evolve. Behind the scenes of autonomous shipping development, a long tradition in maritime technologies and operating environment is getting mixed with Finland’s existing information technology know-how resources. This combination has pushed the autonomous shipping development into its current growth path.

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