

# **Risks & Opportunities of Autonomous Shipping**

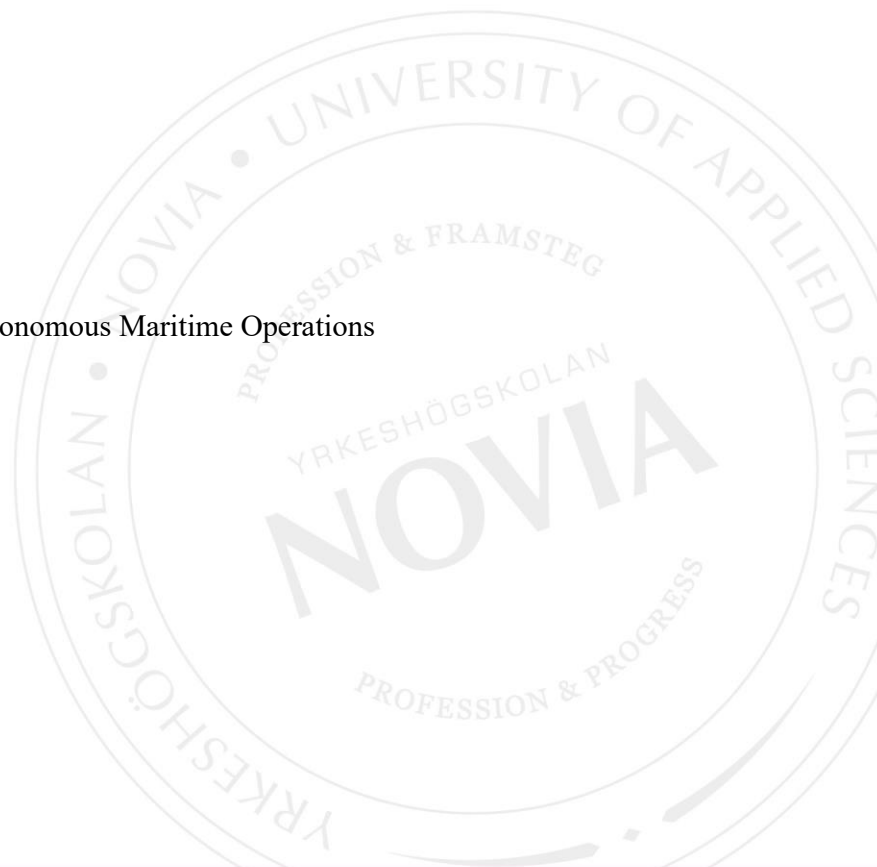
## **Should Shipping go Autonomous?**

Palemia Field

Master's thesis

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Author: Palemia Field

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Supervisor: Dr Thomas Finne

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### Abstract

This thesis explores the feasibility of implementing autonomous shipping and its potential business model in operating Maritime Autonomous Surface Ships (MASS). It provides a brief historical overview before analysing existing literature to identify possible application areas for MASS. In addition, a few Master Mariners who have transitioned to shore-based roles were interviewed to validate the findings and gauge interest in further exploration. The collected data was then subjected to a SWOT analysis to summarise the information.

MASS offers potential in specific sectors. They provide increased efficiency, decreased expenses, and heightened safety, but regulatory issues, human factors, and liability concerns must be resolved. The importance of customer value within the operational model will continue to drive the need for functional change. The role of humans in seafaring trade will hinge on trade, legislation, and connectivity, but people will undoubtedly play a role.

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*“When some one inquired which were more in number, the living or the dead, he rejoined, ‘In which category, then, do you place those who are on the seas?’”*

**Diogenes Laertius on Anacharsis**

*“Worse things happen at sea, you know.”*

**Eric Idle**

## **Abbreviations**

AI	Artificial Intelligence
IMO	International Maritime Organization
MASS	Maritime Autonomous Surface Ship
MEPC	Marine Environmental Protection Committee
MOU	Memorandum of Understanding (with respect to Port States)
MSC	Maritime Safety Committee
ML	Machine Learning
P&I	Protection & Indemnity insurance

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# 1 Introduction

Commercial shipping exists to achieve a defined transport task (carrying freight, passengers, or both) with capital assets (“ships”), ideally to deliver a profit to the company’s owners. The global shutdown caused by the coronavirus pandemic in 2020 affected people and emphasised the far-reaching and interconnected nature of our supply chains. Issues such as managing crew changes or providing critical maintenance services against a backdrop of rapidly developing quarantine slowing down operations (or, in some cases, completely shutting down) to the point that there were empty shipping containers that were still present “in consumer countries and not returning to manufacturing ones” (Wright, 2020).

While seemingly innocuous, the dislocation of shipping containers between supply and consumption economies significantly impacted the global economy during the 2020 pandemic. According to estimates, around 6,000 vessels are accountable for container shipping worldwide. While this represents a smaller subset of the just over 100,000 ships that form the backbone of global cargo shipping, container ships carry 52% of global seaborne trade. This is due to the size of the container ships being able to transport about 8,7 billion US dollars in 2019 (Nikolopoulos, 2022). Even in 2020, during the Covid-19 pandemic, ships moved approximately 408 million twenty-foot equivalent units, which represents a drop of only 1.2% from 2019 volumes, according to the United Nations Conference on Trade and Development (UNCTAD, 2021, p. 17).

Meanwhile, approximately 15,400 ferries operated in 2019 to carry at least 4.3 billion passengers and 373 million vehicles, with their scope ranging from small river crossings to large Roll On/ Roll Off ferries plying their trade in the Baltic and Mediterranean Seas (Oxford Economics, 2021). During the 2020 pandemic, passenger numbers plummeted. Still, the significance of maintaining cargo flows remained, with national governments needing to support operators through financial support to maintain the viability of cargo links on shorter coastal routes. To ensure safety during the pandemic, crews needed proper training in operating vessels while taking appropriate precautions against the coronavirus.

The focus of this thesis is to understand a potential business model behind the deployment of autonomous shipping and, potentially, how to provide a framework for establishing such a model. While the pandemic has driven a shift to work-from-home models for shore-based workers, what about a similar model for those at sea and the marine industry? This thesis scopes out the necessary information by reviewing the history of shipping and Maritime

Autonomous Surface Ships (MASS) to provide an early context of how shipping has evolved.

## 1.1 History of Shipping

Moving goods in the maritime domain has been a feature of human existence for over four thousand years. While propulsion methods have changed from sail to diesel to electric in that time, the fundamental principle of shipping is the same today as it was for the Minoans, that is, to trade goods for profit and run the ships as efficiently as possible. Throughout history, goods have been exchanged across Europe by different civilisations, and coastal vessels have also contributed to the growth of populations worldwide. The most dramatic migrations, however, occurred in the Pacific, where Polynesians executed deep sea and over-the-horizon voyages of significant distances some 3000 years ago with people, agricultural support, and animals such as pigs and chickens (Skoglund et al., 2016).

Throughout human history, wind-powered sail configurations have been the primary source of propulsion for commercial marine traffic. However, oars have been historically favoured for fighting vessels due to their superior manoeuvrability. As a result, ship crews have traditionally focused on managing the sails and navigating the ship, with the team working together on the outer and upper decks.

In the 19th century, coal-fired steam-powered ships replaced commercial sailing ships. Initially, reciprocating steam engines with paddle wheels or propellers were used before the introduction of marine turbines. Charles Parsons invented and incorporated the compound steam turbine, inducing a necessary increase in crewing on board. While previously, the navigation and management of sails were handled by what is now called the deck crew and officers, the new form of propulsion required specialist personnel who could operate and maintain this new machinery and act in response to propulsion requirements sent from the navigational bridge. Initially, this mechanical propulsion was in a hybrid configuration with the mainstream sailing configurations of the time. As the age of mechanical propulsion detached the delivery of passengers and goods from being highly influenced by the prevailing weather conditions along with higher speeds and efficiencies, markets adjusted to this more predictable routing. A wholesale shift to mechanical propulsion saw the end of sailing ships plying the oceanic trade just after the Second World War (Ålands sjöfartsmuseum, 2021).



Today's oceangoing vessels typically operate with a crew of approximately 20 persons, divided into the Deck (Nautical) and Engine (Technical) Departments. The departments have a staff hierarchy with officers managing the ship or operations on board, specialists such as motormen, electricians or boatswains, and lower-skilled ratings such as oilers, wipers, or deckhands (Deloitte, 2011). For specialised vessels such as cruise ships or warships, an increase in the ship's crew would be the norm to facilitate the additional functions on board. Taking this to extremes, the world's largest cruise ship as of 2023 is *Icon of the Seas*, which Royal Caribbean International will operate. The ship's crew will number 2350 to cope with the maximum passenger capacity of 7600 guests (Royal Caribbean International, 2023).

## 1.2 Regulation of Shipping

Modern-day shipping is a complex construct spanning multiple legal jurisdictions as a result of ownership, areas of operation, crewing and legacy issues. Understanding the evolution of the regulatory framework within which today's shipping industry operates is critical to understanding what legal hurdles influence ship design and operation in the 21st century.

Whilst the concept of an international maritime body was mooted "at the end of the 19<sup>th</sup> century by a Russian lawyer P. Kazansky" (Bekiashev & Serebriakov, 1981), it was not until 1959 when the first meeting of the then-named Inter-Governmental Maritime Consultative Organization (IMCO) took place as the permanent United Nations body responsible for supporting international efforts towards maritime safety. The IMCO became the International Maritime Organization (IMO) following a name change in 1982. Specifically, it provided a mechanism "for cooperation among Governments... relating to technical matters of all kinds affecting shipping engaged in international trade" (United Nations, 1948). Shortly after that, four significant conventions and treaties regarding the maritime industry were transferred to the fledgling IMCO under its mandated "Maritime Safety Committee" (MSC):

- Treaties for preventing collisions at sea
- International Load Line Convention 1930
- International Convention for the Safety of Life at Sea of 1948
- International Convention for the Prevention of Pollution of the Sea by Oil 1954

This Committee was responsible for:

aids to navigation, construction and equipment of vessels, manning from a safety standpoint, rules for the prevention of collisions, handling of dangerous cargoes, maritime safety procedures and requirements, hydrographic information, log-books and navigational records, marine casualty investigation, salvage and rescue, and any other matters directly affecting maritime safety. (United Nations, 1948, p. 62)

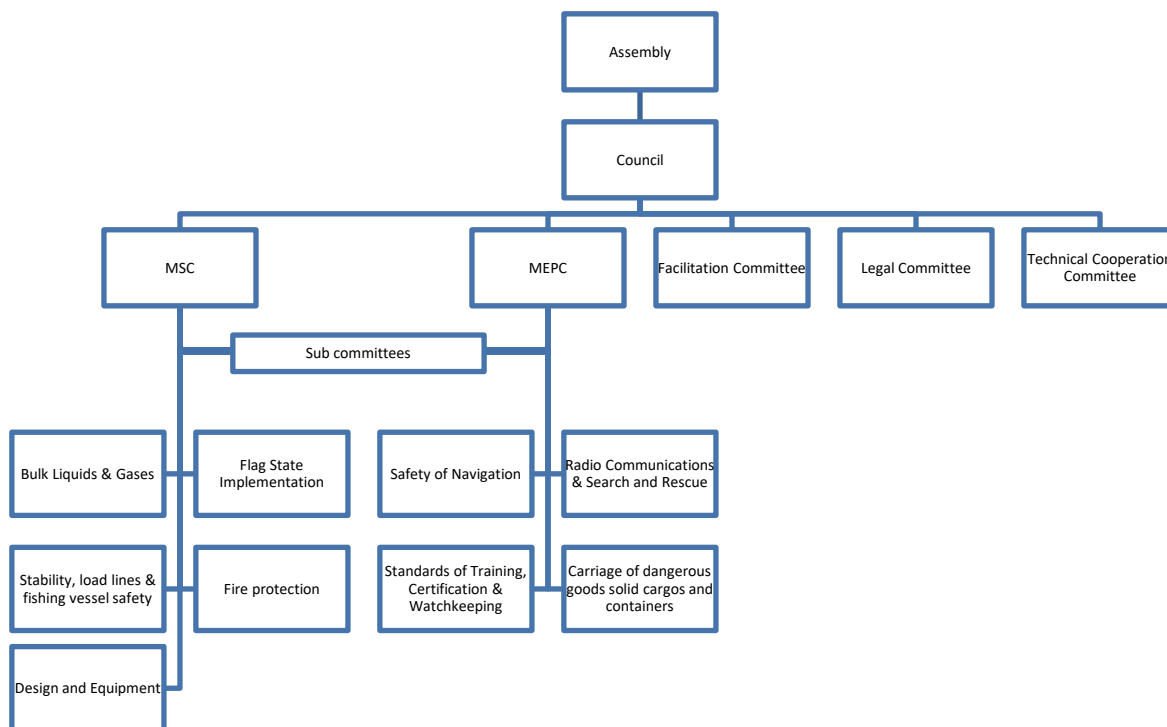
The MSC remains responsible as defined in the initial Convention text and consequently is the most senior of the committees. However, four more committees have been formed since the IMO's inception. In the following list, the dates in parentheses indicate establishment by the IMO assembly (IMO, 2016):

- Marine Environmental Protection Committee, "MEPC" (1985)
- Legal Committee (1975)
- Technical Cooperation Committee (1984)
- Facilitation Committee (2008)

In addition to the MSC and MEPC, some sub-committees impact the implementation and control of MASS globally, which will be explored more in-depth in the thesis. A simplified arrangement of this organisation is presented in Figure 1.

**Figure 1**

*IMO Organisational structure (Russell & Coles, 2018)*



The IMO does not write laws for immediate application in geographic jurisdictions. Instead, the Assembly agrees upon Conventions, Codes and Resolutions upon receiving them from the committees. Once ratified by the necessary process, the member states are obliged to implement the relevant rules within their domestic legislation, thereby enabling the executive function of the government to apply the conventions as necessary.

Enforcement agencies are then empowered to regulate the IMO conventions either under the country in which the ship is registered (“Flag State”) or that of which it is visiting (“Port State”). Ports States manage regional consistency through an “interadministrative accord” known as a Memorandum of Understanding (MOU), the first of which was agreed in Paris in 1982. This is now referred to as the Paris MOU, with eight more MOUs established since then, subdividing the globe into geographical areas (Prouzet & Monaco, 2015, p. 73).

### 1.3 Shipping structure

Today, shipping comprises prominent constellations or consortia of elements that have evolved from four thousand years of water trade. It has represented the ability to trade and contributed to global events such as the Opium Wars in the 19<sup>th</sup> century. While a minority of shipping companies are publicly listed, most shipping lines operate opaquely to mitigate the risks of their operations. It is also an invisible industry to the general population, even though some companies may be trading in revenues similar in scale to Coca-Cola or Microsoft (George, 2013).

The shipping industry carried almost 11 billion tons of cargo in 2021 (UNCTAD, 2022), bringing the volumes close to the amount before the Covid-19 pandemic. What surprises the layperson is the time a ship spends in port, with the United Nations Conference on Trade and Development's median time in the port of just over one day. This efficiency in cargo management is seen across all ship types, with bulk carriers being a slower outlier. Speed and efficiency will be demanded because of online commerce, which also drives demand for new ships and crews, although this consumer volume could represent as little as 6% of global trade.

Marine trade is responsible for around 80% of global trade by volume, and it is a relatively consolidated market, with the top four shipping lines carrying almost 60% of the trade (UNCTAD, 2022). Further rationalisation of this trade is present with the formation of shipping alliances like Star Alliance, oneworld and Sky Team in the passenger aviation sector.

Barriers to entry exist in more than just a financial sense. An interwoven system of contracts, existing markets, and a diverse regulatory framework make incumbents solid and able to defend their position against newcomers that enter from a weak point of entry (Fusillo, 2003). Established shipping lines benefit from economies of scale by distributing their investment costs across larger fleets and having the security of fuel and other supplies through long-term supply contracts. As new regulations enter to drive the environmental performance of shipping further towards a lower-impact industry, any additional Capex, OpEx and compliance costs are more straightforward to distribute across a more extensive fleet.

## 1.4 History of Maritime Autonomous Surface Ships (MASS)

There is a misconception that the discussion on autonomous shipping began in 2015 (Munim & Haralambides, 2022). In contrast, the first documented dialogue on the subject occurred within the MSC in 1964. The MSC was invited to consider the “various aspects of the problem.” Already then, distinctions were made between “a fully-automated system, a partly-automated system and remote control”, where automation was to “adjust and control their performance with little or no human intervention, once the operations is started” (IMCO, 1964). During discussions, the potential clash concerning the manning of ships was “primarily of the concern of the ILO [International Labor Organization] though at some points the interests of IMCO, particularly in regards to safety, might overlap.” However, it was decided at that “stage complete automation on board was impossible” (IMCO, 1964).

Ninety committee meetings later, at MSC 98 held in June 2017, the MSC included in its workflow an output, “Regulatory scoping exercise for the use of Maritime Surface Ships (MASS)” targeted for completion in 2020. This was in response to a proposal submitted by multiple member states requesting that the work program provide an understanding of “the full range of regulatory implications arising from MASS and plan appropriately” (MSC, 2017). The proposal paper suggested that should the IMO fail to act, the “proliferation of MASS in an unregulated manner” would occur, “which may lead to adverse impacts on maritime safety, security and the protection of the marine environment.”

Indeed, this is not to say that research into MASS had not occurred from 1964 to 2017. At its 1964 meeting, the MSC recognised that Norway was already “in the van” of reduced manning from technologies deployed on Norwegian bulk carriers. MS Haugvik was delivered with a novel system to enable engine room monitoring from a bridge panel in February 1964. While challenges arose from this new operational method, DNV introduced the E0 class notation, allowing for a periodically unattended engine room in 1966. The typical operational profile for vessels with an E0 notation would have left the engine room unmanned at night. Then, the ship’s automation system would alert a duty engineer during the night to attend to the machinery spaces should an abnormal event occur. During the day, the engineers would be engaged in regular maintenance work. However, initial results from “E0-operation did not result in any reduction of engineers, but it resulted in a better maintenance of machinery” (Höivold, 1984).

The restart of deploying autonomous or intelligent ships was carried out under the auspice of the Maritime Unmanned Navigation through Intelligence in Networks project (MUNIN).

Funded by the European Union, the programme intended to “develop and verify a concept for an autonomous ship” and was carried out between 2012-2015. With its various work packages, the closing report from MUNIN back to the EU was that “an autonomous vessel is technically feasible... A MUNIN bulker would be commercially viable under certain circumstances” (Burmeister, 2016). MUNIN assumes that by changing the ship design, personnel costs can be reduced, and the vessel's value can be improved over the 25-year period it is expected to be in use. The value would be associated with reductions in fuel, along with the related emissions, and the increased safety perceived with a “decrease of collision and foundering risk by around ten times compared to manned shipping... due to eliminating fatigue issues” (Burmeister, 2016). The report acknowledges challenges with cybersecurity, mechanical breakdown issues and ship integrity issues related to fire but assumes that resilient design and redundancy would provide sufficient mitigation.

Further, EU projects in the MASS domain included the DNV GL ReVolt project and the Finnish-funded Advanced Autonomous Waterborne Applications Initiative. Starting a year after the MUNIN project, the Norwegian/ Dutch registrar and classification society DNV GL commissioned the ReVolt research project in 2014. Looking at short sea routes at a speed of 6 knots for 100 nautical miles, the vessel that could carry 100 TEUs without crew was estimated to save “a million USD annually.”

The Finnish-funded Advanced Autonomous Waterborne Applications (AAWA) Initiative extended the concept that MUNIN had considered to include when “there are no people on board, many constraints on the ship layout are removed” (AAWA, 2016). This removes the accommodation block with consequential cost, weight and space-saving, which can be translated to increased payload or fuel saving, essentially concurring with the MUNIN study.

While European projects investigated MASS in the theoretical sense, where they are motivated by the need to reduce emissions and cost efficiencies, Japanese demographic pressures are driving the push to MASS because “more than half of coastal shipping crew members [are] over the age of 50” leading to concerns that the country will soon not be able to sustain crew sizes at the current levels (The Nippon Foundation, 2022). As an archipelagic country with about 400 inhabited islands, coastal traffic is critical for freight and community lifelines.

This led to a real world test in March 2022, when the cargo ship Suzaku completed an almost 430 nautical miles voyage from Tokyo Bay to Ise Bay. The cargo vessel was retrofitted with the necessary equipment for autonomous navigation and machinery monitoring, feeding

information to a fleet operation centre via a satellite connection. Unlike the Norwegian-owned and operated *Yara Birkeland*, the Japanese vessel could complete the entire voyage, including undocking and docking, on its own without the assistance of a human crew.

Interestingly, Japan and European nations increasingly recognise the need to position the maritime industry as an appealing career path with work environments similar to those of other occupations. The COVID-19 pandemic demonstrated that remote work is possible in various workplaces, although the distribution of this phenomenon was undoubtedly different across industries or locations (Crowley & Doran, 2020). While the previously mentioned 120 TEU cargo vessel *Yara Birkeland* has been delivered, exploring how different work methods are best managed for the industry continues. The *Yara Birkeland* operation of displacing road transport can be viewed as a guide to influencing existing operational strategies. It is the change in operational strategies that has the potential for disruption from external players such as Amazon, which is likely due to the “cost base and infrastructure base [which] may be irrelevant quickly” for current operators (Meling, 2019).

## **1.5 Purpose and research questions**

As mentioned previously, MASS research has seen a significant resurgence in the last decade. While autonomous operations are available ashore and in aviation, maritime digitalisation has been limited to sub-systems such as machinery monitoring and autopilot systems. The rationale for moving more operations towards automatic and autonomous control is the intent of the MASS discussion at IMO now that the potential impact on international regulations has been completed. While the MUNIN, ReVolt, AAWA and MEGURI 2040 studies looked primarily at technical implementation, resulting in the “how” and “what” questions, the “why” question was looked at from rather broad macro motivations such as environmental, crewing or incidents arising from human errors.

Environmental regulations are increasing pressure on the shipping industry. For example, the EU Emissions Trading Scheme (ETS) introduces a carbon cap-and-trade system with respective conversion factors based on fuel burnt within the EU or to and from EU ports (Directive (EU) 2023/459, 2023). Does MASS have the potential to successfully mitigate this newer business operational expense to offset other OPEX costs, or could a part solution with digitalisation or automation be sufficient?

Regarding crewing, most ships are already at a point where automation has reduced the need for direct onboard headcount. Indeed, a “40,000-tonne ship built in the 1950s could have 50

crew. A similar size ship built in 1990 could have 20, and the latest container ships may run with 13” (Shaw, 2023). Does the law of diminishing returns impact the business operation of a ship when the remaining crew can still carry out maintenance while the vessel is on charter as opposed to a riding crew going on board once the ship is alongside and unable to produce revenue?

Finally, marine incidents constitute a significant cost for shipping operators and a risk for those who rely on ships to feed lengthy supply chains. Allianz Global Corporate & Speciality, an insurance firm, registered 54 large ships lost at sea in 2021. But Allianz also noted that compared to the rolling 10 year loss average of 90 ships per year, 2021 was a significant improvement. This reduction in ship losses globally contradicts the trend of the increasing number of ships, where now approximately 130000 ships of over 100 gross tonnes are trading today. This compares to “only” 80000 ships of similar size being a part of the 1990s fleet (Allianz, 2022). The same Allianz report suggests that “75% of shipping incidents involve human error, ” also cited in motivations for MASS deployment. A potential real-world use case where this human error overlaps with the hull losses uses AI to identify collision risks where the Convention on the International Regulations for Preventing Collisions at Sea (COLREGS) apply and the potential for misunderstanding between the bridge teams of the two ships exists (Lehtovaara & Tervo, 2019). Could AI negate the 75% human error statistic?

Essentially, shipping is the business of moving “stuff” profitably. Losses in commercial operations are typically the result of a risk being realised or not compensated for in the industry. Before establishing the business case, the technical assessment was carried out in multiple studies, allowing a gap analysis to occur.

While technical papers from the past ten years abound in the research databases, this paper proposes an understanding of the business of MASS. Specifically, “what are the risks & opportunities with autonomous shipping?”, and, “is it possible to create a business model for autonomous shipping?”

## **1.6 Thesis Structure**

The research in this paper intends to understand three major elements:

1. The Vernacular.
2. The Process Design; and,



### 3. The Definition of “How Much”.

In his 2022 article, Shaw discusses the need to be coherent. Communicating accurately and purposefully requires a vocabulary appropriate to the context of MASS operations. This topic is part of a larger conversation about autonomous technology across various industries beyond transportation, including ongoing research in areas like industrial machinery. However, the exact meaning of “autonomous” requires specification. The Oxford English Dictionary (2022) refers to autonomous as only meaning “[d]enoting or performed by a device capable of operating without direct human control”. One must compare this to the definition of automatic “(of a device or process) working by itself with little or no direct human control” (Kielikone Oy, n.d.). With such a close definition for both terms, establishing language to define the terms and subsequent impacts on both regulatory and business models is critical to the successful outcome of this thesis.

Once the term “autonomous” is clarified, what impact does using autonomous technologies have on the marine business? Much is made of ships' increased connectivity to shore, enabling two-way communication. Nevertheless, an autonomous ship should only need a connection to shore once it is ready to tie up and offload its cargo. What does removing humans do to the decision-making loop, and are humans ever indeed removed completely?

Finally, what type of business models can be deployed using autonomous ships? Is it possible to deploy such models across the entire shipping fleet, or would it be more suitable to deploy into an assumption that autonomy is suited to different categories of vessels or operational profiles?

## 2 Research Methodology

Before the participant phase, a comprehensive literature review was conducted to identify key themes, concepts, and gaps in the existing knowledge related to the research area. The literature review served as the initial step in crafting the interview questions by providing insight into the prevailing issues, controversies, and areas that required further exploration.

The narrative literature review was carried out to establish a basic understanding of the knowledge in the MASS domain, focussed on a more business-oriented, rather than a technical, focus. A narrative literature review “documents, analyzes, and draws conclusions about what is known about a particular topic” (Machi & McEvoy, 2022). Given the two questions, the literature review was conducted in two strands. One was to establish what was

known regarding “business models”, particularly given the phrase "business model" is a term yet to be accepted unilaterally, and a rudimentary definition is presented in this research as a framework to proceed forward. The second string considered literature on Maritime Autonomous Surface Ships and why such vessels could make sense commercially.

While the literature review was undertaken to understand the current state of knowledge on the deployment of MASS, a qualitative investigation is needed given that very few cases of autonomous surface ships are being used commercially, ruling out any quantitative research. Pickard (2022) suggests that “[i]nterviews are appropriate when the purpose of the researcher is to gain individual views, beliefs and feelings about a subject”. One could consider a survey, particularly with the increase in online surveys, where “a global change in research pattern has been noticed” (Kumar et al., 2021). Kumar et al. identified the risk of web-based surveys, particularly issues of coverage bias. Suppose a researcher needs to take the input of seafarers on the impact of MASS on their profession. In that case, the quality of the Internet on ships in deep water traffic is “described as poor and often expensive” (The Mission to Seafarers, 2023) and would be a barrier to completing the survey. Additionally, the suspicion by seafarers about how MASS “might threaten job security” would introduce bias (conscious or otherwise) with the potential to detract from the research itself (Kelly, 2023).

In discussion with Novia AMK staff, the semi-structured interview method with a smaller group of candidates who had a profile of having worked at sea were now in supervisory roles ashore (either part or full time) and had commanded a merchant ship at least once was decided upon.

## **2.1 Previous research**

In reviewing the literature, a search was conducted using both the Alma-Novia and Google Scholar databases, using key search phrases such as "Maritime Autonomous Surface Ships," "autonomous shipping," "business models," and related terms. Only peer-reviewed journal articles, conference papers, and reports written in English were considered. Irrelevant papers and duplicates were excluded. These netted 80 papers that were then screened for categorisation in at least one of the following themes:

- Safety
- Legal

- Workforce
- Operational Efficiency
- Financial Efficiency
- Environmental Consideration
- Liability
- Security
- Reliability
- Human Factors

A qualitative analysis needed to be carried out to understand the research questions better. This involved identifying patterns in the text to guide the analysis towards a resolution. Articles focused on resolving technical challenges in MASS infrastructure, while numerous, were excluded as they did not contribute to answering the business case questions.

It is important to note that any literature review may have limitations, such as reliance on published literature, potential publication bias, and exclusion of papers not written in English. However, efforts were made to minimise these limitations by systematically searching databases and including various publications. Most publications were published after 2016, but the search was conducted from the inception of available literature within the databases.

## **2.2 Interviews**

In addition to providing the basis of this thesis, the previous research also allowed the framing of questions for semi-structured interviews of master mariners who were now working ashore. The following questions were presented to the interview subjects in advance to provide some structure to the questioning path:

1. What sector do you operate in, and what are the geographical areas of operation?
2. What metrics do you use to consider if a ship is performing well or underperforming?

3. Do you own your ships directly, or are you chartering? Do you trade the ships yourself, or are they chartered out?
4. What is your business, and what is your business model? Who are your customers? What impact do on board staff have on fleet operations?
5. How do you think MASS will impact your operations at the ship level/ fleet level/ shore operations? How do you see the impact on the total cost of ownership of a ship?
6. What problems will autonomy solve? Do you see further issues or potential unintended consequences?
7. To what degree of autonomous or automatic technology would be a comfortable first step?

The semi-structured interview questions were developed throughout this research with a deliberate and informed connection to the existing literature. This section elaborates on the methodology used to ensure the questions were based on a solid foundation of existing knowledge while minimising the potential for researcher bias.

The literature review identified prominent themes, theoretical frameworks, and gaps in the current research landscape. These findings guided the formulation of interview questions that delved into well-established topics and explored underexplored or contested areas. The interview questions were adjusted and customised based on this thesis's specific context and objectives. The questions were required to answer the research questions of this thesis.

To minimise the potential for research bias, the researcher maintained a critical approach and an awareness of potential research bias based on their current and previous professional roles. While some questions may have been developed based on existing knowledge, further work would be needed in terms of focus groups to test the questions for the presence or lack of research bias.

A reflexive stance was maintained throughout the research process, allowing for modifying and adapting interview questions as new insights emerged from the data. This flexibility ensured the research remained responsive to unanticipated findings and evolving objectives.

Interviews were carried out with six candidates who were selected based on having been, or currently, in command of a ship and were known to the author before the research was

carried out. Participants' consent was given and recorded as part of the interview process (Gillham, 2000, pp. 37-43). They represent different ship types to mitigate any views in one segment of the marine industry but also to help identify where differences exist between the segments and potential opportunities. The semi-structured interview format was adopted, allowing the prepared questions to be answered for further analysis and an opportunity to investigate new ideas. The interviewees were not provided with direct MASS definitions before the interview. Instead, the research relied on the seafarers being aware of MASS in the industry and what it meant to them. This was a deliberate action to offset the potential research bias that would be incurred by supplying information from the research.

All interviewees were interviewed via Microsoft Teams. This allows *in situ* recording of the interview for accurate transcription and increases the opportunities to interview the masters at an appropriate time. Participants provided consent to the recording. While it was made clear to all participants that the interviews did not require them to deliver confidential information, the identities are confidential to the researcher.

One of the drawbacks of conducting interviews is that only a limited number of people can be interviewed. In the case of seafarers, there are none with practical experience in operating MASS technology, let alone establishing a business model for their use. To address this issue, in conjunction with Novia AMK staff, it was concluded that gathering feedback from a smaller group of qualified interviewees against a more significant number of anonymous online survey responses from unknown or unvalidated persons would provide a suitable compromise to answer research questions with accuracy.

## **3 Previous research**

### **3.1 Other fields of autonomy**

Autonomous technology is finding its place in various transport and industrial processes. Typically used in areas/methods that are dirty, dangerous, or dull, autonomous technology is used to replace the human effort where either the danger or discomfort to humans is intolerable, or the cost of doing such a job by a human is not paid at a level where it is worthwhile.

Autonomous technology generically is defined as the ability of machines or systems to operate independently without human involvement to solve problems arising from that operation. The ability to adjust, adapt and infer further operational performance is a crucial

differentiator from automated technology, which is seen as a simple single-loop control problem.

For example, an autopilot system on a ship will always respond the same way to a course change according to the variables in the PID control<sup>1</sup>, independently of the number of times control logic is used. An automatic system will only change if a set point is changed or the control variables are adjusted (Russell, Jackson, & Morton, 2018).

Autonomous systems engage machine learning and artificial intelligence to learn from experience, integrate changing scenarios or optimise process output over a longer time window than automatic systems. In domains such as cybersecurity, this allows an autonomous system to react to a highly dynamic threat environment and then predict based on patterns that recur at rates higher than a human could process (Shu et al., 2020).

### 3.2 The Language of MASS

A helpful 2022 definition from the Technical Research Centre of Finland (VTT) on autonomous vehicles uses the following:

Autonomous industrial vehicles and machinery are driverless. The vehicle or machinery itself carries out specific tasks without human intervention. In practice, this requires sensors that interpret the operational environment and artificial intelligence that makes decisions based on the sensor data.

Moving into a more domain-specific definition, in his 2016 paper on integrating autonomous technology with the human element, Ahvenjärvi posits, “an autonomous ship is a seagoing surface vessel which is capable of operating without any crew onboard.”

Many of the papers in the domain looking at autonomous shipping focus on the navigational aspect of a ship. That is, to take a vessel from its port of departure to the intended port of arrival completely without involvement by **the onboard crew**. This differentiator will be critical in the future business analysis of autonomous shipping. VTT communicates the need for the ship to analyse the environment to adapt the control outputs of the machinery or vehicle, creating a digital situational awareness and removing the human in the decision-

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<sup>1</sup> PID= Proportional, Integral, Derivative control. In control systems, a standard method is to regulate the output of a process to a set point. PID describes the three components of this type of control algorithm.

making loop. Therefore, the simplistic view of autonomous shipping would be the operation of a ship crewless.

Autonomous operations in commercial transport are seen as a critical cost reduction by increasing potential payload, thereby reducing cost per goods carried and eliminating the personnel cost of the human operator (whether as pilots or drivers). As an example, the qualifications of personnel are very specialised. Under European Union requirements, aircrew certification is based on flight operations and procedures (EU, 2011):

“We need to know the systems, where the box is... what they do. But how to fix the box? No.” (T. Avikainen, personal communication, April 16, 2023)

Maintenance staff are similarly but separately certified in that just as pilots are rated for a particular aircraft type, commercial maintainers must demonstrate the competence and currency for theirs. Therefore, in the commercial aviation world, at least, the autonomous navigation of aircraft can be achieved under current operational profiles with approved regulation changes.

Competencies and certification for marine crews, on the other hand, have developed to operate ships as well as the maintenance and management of the vessels within the context of a business operation. This applies to the officers on board and the support staff of technicians who are expected to function as operators and maintainers. Recognising that “multiple crew members are responsible for many tasks other than ship handling” can require the crew to remain on board even if the only autonomous function is the ship’s own navigation (Wariishi, 2019). If a ship is to be navigationally autonomous, that is, “operating without any crew onboard”, what to make of the non-navigational tasks?

Therefore, as part of the vernacular of Maritime Autonomous Surface Ships, it is essential to establish that while a ship may operate autonomously, the decoupling of this operation from onboard crewing levels will need to occur. The challenges in this are the regulatory environment that shipping operates under, where it is assumed that the crew is on board, available and at specific locations of the ship (i.e., the wheelhouse where a certified “Officer of the Watch” must be in attendance). Indeed, the role of the “Master” is also a challenge as the Master (also referred to as the captain) “has all the responsibility concerning all matters that happens to the ship or that requires by the laws and regulations” (Li & Fung, 2019).

In 2017, the IMO began working on establishing terms for a Regulatory Scoping Exercise (RSE) to address identified regulatory issues due to “an increased deployment of MASS to

deliver safe, cost-effective and high-quality results” and that “[s]ignificant academic and commercial research and development (R&D) was ongoing on all aspects of MASS” (IMO, 2021). This exercise defined MASS “as a ship which, to a varying degree, can operate independent of human interaction.” The scale of autonomy used was a four-tier level where technology and crewing were combined, resulting in a situation where the difference between the lower two levels of autonomy and upper levels related to the presence of crew being on board or not.

The RSE also identified the need to clarify terminology. It is premature and presumptuous that a comprehensive vernacular will be satisfactorily specific in the scope of this research. However, the following terms are defined to proceed further:

Autonomous Ship	As defined by Ahvenjärvi (2016), that is, “a seagoing surface vessel which is capable of operating without any crew onboard”.
Remote Controlled Ship	Ships operated by a remote centre situated off-board, in compliance with existing regulations. This can also pertain to ships undergoing MASS trials.
Conventional Ship	A vessel operated under existing legislation as of 2023 with no dispensation for reduced crewing while in compliance with its Safe Manning certificate.
Master	As defined in UNCLOS <sup>2</sup> , “the person having command or charge of a ship”. According to standard procedures and conventions, it is expected for the Master to be present on the vessel.
Crew	As defined in STCW <sup>3</sup> , “any person who is employed or engaged in any capacity on board a seagoing ship.”

Different models exist to establish levels of autonomy, such as the IMO’s four-level table and the Society of Automotive Engineer’s six levels of autonomy for road vehicles. However, this terminology will not be considered in this research to minimise the influence of the speculative nature of the regulations today. The rationale is that the ship has rather

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<sup>2</sup> United Nations Convention on the Law of the Sea

<sup>3</sup> International Convention on Standards of Training, Certification and Watchkeeping for Seafarers



more gradation between these levels due to the operational nature of ships. These levels of automation have been the subject of dedicated research highlighting the issues surrounding the responsibility in an autonomous system. This research into the autonomous system's scope of responsibility could result in autonomous operations based on unachievable technical capabilities due to such a high requirement (Myhre et al., 2019).

### **3.3 Perceived pros and cons of MASS**

Autonomous shipping utilises varying levels of automation, “from partially automated systems that assisted the human crew to fully autonomous systems which were able to undertake all aspects of a ship's operation without the need for human intervention” (IMO, 2021). The potential to change operational processes comes with risks and challenges concerning the technology field (The Honourable Company of Master Mariners, 2023). While the opportunities include the potential for increased safety, efficiency, cost reductions and benefits concerning the environment, concerns are raised quickly to counter these benefits. The possibility that an autonomous ship is less safe than those in the incumbent fleet, the regulatory framework, and the social impact of workers' displacement will demand robust testing and regulation to achieve a level that they are at least as safe as current ships.

#### **3.3.1 MASS Safety**

The first consideration when considering safety in the MASS context relates to the safety of the human crew. Safety is “the condition of being protected from or unlikely to cause danger, risk, or injury” (MOT Oxford Dictionary of English, n.d.). In the maritime domain, risk can be defined as “the combination of the frequency and the severity of the consequence” (IMO, 2018). Further, the IMO establishes that maritime safety includes the “protection of life, health, the marine environment and property”.

Simply put, this elimination of onboard crew means the non-existing humans on a ship will not be injured or killed on board. Nor will humans be required to operate on board under heavy fatigue or high workloads that plague the industry today (Felski & Zwolak, 2020). This ability to remove humans from harm's way allows the deployment of vessels into dirty, dull, or dangerous situations. An example of this is underwater remote-operated vehicles (ROV), where it would be unfeasible to put a vessel into deep water where the additional engineering required for a habitable space would be unfeasible.

However, the requirement to have sensor data collected and processed by artificial intelligence, as well as decisions made and transmitted over computer networks on board, presents a far greater vector for a cyber-attack than exists in current ships. The literature acknowledges that even an autonomously operating ship will require remote monitoring, opening another threat vector that could be utilised for nefarious means. Concerns surrounding the spoofing of navigation systems that operate on satellite signals are already driving an industry-wide response in cybersecurity, resulting in the matter being addressed as part of the ship's safety management system. It continues to be a threat that has been augmented by geopolitical conflict where "the worst-case scenario is a terrorist attack or nation state group targeting shipping", which could result in a ship causing indirect damage to economies by disrupting trade routes (e.g. Ever Given's grounding in the Suez Canal) or direct damage by using the ship as a virtual battering ram (Allianz, 2022).

Finally, the biggest issue surrounding humans and autonomy has the potential to unravel decades of assumptions about the human element.

### **The 80% issue**

Across the literature reviewed, a common statistic arises which is not just endemic within the maritime industry but almost to the point of inalienable fact, "80% of marine casualties are caused, at least in part, by some form of a human error" (Ahvenjärvi, 2016)

This statistic was cited in 13 of the 80 papers reviewed as part of the research for this paper. The difficulty is that the statistic is mentioned in papers without data, making it extremely difficult to replicate the result (Wróbel, 2021) and citing tends to be tertiary. In his research, Wróbel considers "that the figure has not been subject to a rigorous verification", and while the quote above comes from Ahvenjärvi's paper, he also questioned the validity of this number. One issue that both Wróbel & Ahvenjärvi agree on is the need for clarification of the term "human error". Another issue is that "the term 'human error' by no means captures all the ways in which people contribute to accidents" (Reason et al., 1990).

While this debate falls outside of the scope of this paper, the language used in autonomous shipping has been a topic of discussion lately. However, the fact that there is no definitive conclusion about accident rates indicates that the problem is much more widespread than initially anticipated.

Although the reported 80% error rate may not be entirely scientifically sound, it is worth keeping in mind that shipping companies are often considered "high reliability

organisations" (HROs). Other HROs include nuclear power plants, hospital emergency rooms, and aviation, where the goal is to develop systems and protocols to prioritise safety and reliability (Klein et al., 1995). In many of the papers presented, eliminating human error is the prime motivator towards autonomous shipping on the basis that this 80% statistic is eliminated, but further research is required to establish the actual savings in human-induced error for maritime operations.

Given potential is available with Machine Learning (ML) or Artificial Intelligence (AI) technologies able to process historical data fused with the available sensor data, the human error statistic may be even higher when one considers "that people design, build, operate, maintain, organise, and manage these systems" (Reason, 1995). Introducing a complex system on board will require new levels of certification under regulations to ensure that the safety of autonomous ships is as safe or safer than conventional ships. The workforce displacement is discussed later in this section.

Another aspect of safety when discussing MASS is what to do about piracy. Piracy (in the maritime context) is defined by Article 101 of the UN Convention on the Law of the Sea; in that, it is:

- (a) any illegal acts of violence or detention, or any act of depredation, committed for private ends by the crew or the passengers of a private ship or a private aircraft, and directed:
  - (i) on the high seas, against another ship or aircraft, or against persons or property on board such ship or aircraft;
  - (ii) against a ship, aircraft, persons or property in a place outside the jurisdiction of any State;
- (b) any act of voluntary participation in the operation of a ship or of an aircraft with knowledge of facts making it a pirate ship or aircraft;
- (c) any act of inciting or of intentionally facilitating an act described in subparagraph (a) or (b) (United Nations, 1982).

While 2022 data is not yet available, the IMO stated that 2021 had "the lowest number of reported incidents at the global level since 1996". The impact of the COVID-19 pandemic is unclear, but still, the crew reported as taken hostage, kidnapped or missing was 40

compared to 135 crew in 2020 (IMO, 2022). However, piracy remains a real and current danger. The ideal situation of uncrewed ships able to transit essential trade routes, including the Malacca Straits, the Horn of Africa, or the Gulf of Guinea, with no threat to personnel is appealing. This could be the critical part of MASS safety as a target where ships are prepared for operation in these areas where the cargo is in a somewhat inert state and more readily secured against unauthorised access.

### **3.3.2 Regulatory Issues**

The biggest threat to the deployment of autonomous ships is quite simple when considered under international conventions: They are not allowed to.

The IMO conducted a Regulatory Scoping Exercise (RSE) to assess how much of a regulatory impact MASS will have. The report issued in 2021 as an outcome of the RSE identified issues across all subcommittees within the IMO, and action is underway to review the regulatory framework. This factor shifts issues toward the liability and scope of responsibility should a marine incident involving a MASS vessel occur. Where does responsibility lie for a ship that operates because of an algorithm? Does it remain with the owner? What happens with no master? These questions arise, given the current assumptions regarding marine liability.

Marine liability is the responsibility that entities face for any damages or losses. The legal and fiducial scope arises from a plethora of incidents, including, but not limited to, cargo damage, demurrage, collisions, pollution, and injury to persons. Various types of insurance are available to manage these risks and can be underwritten in different ways (Downward, 1999). Given the large sums of money at stake, a quirk of insurance in the marine industry is Protection and Indemnity (P&I) insurance. Typically used in marine casualties where the potential financial risk could be more evident, shipowners establish P&I Clubs for mutual insurance where regular commercial underwriters would be unable or unwilling to provide cover.

Therefore, the two major issues concerning the regulatory aspects of MASS relate to the regulations themselves and the allocation of liability, where the implementation of risk management remains uncertain. It's important to note that the regulatory landscape for MASS is complex and evolving, and different regions may adopt varying approaches at different speeds. This potential variation introduces a significant level of uncertainty and can be a barrier to MASS's widespread deployment and development.

The IMO issued recommendations in 2019 toward member states for MASS trials, empowering member states in running trials “safely, securely and with due regard for protection of the environment” (IMO, 2019). However, the path towards regulatory uniformity on a global scale is not yet clear. It is conceivable that domestic MASS applications will be easier to achieve in the foreseeable future, serving as valuable data-gathering tools, especially the widespread adoption of MASS for international trade. The extent to which maritime conditions and regulations will be universally adopted or vary across regions is an ongoing area of exploration in the industry.

### **3.3.3 Workforce**

The implementation of autonomous shipping could result in workforce displacement, potentially causing crew members and other workers in the shipping industry to lose their jobs. Shipping has evolved as technology presents itself, but while technology has allowed a reduction in crew numbers, mainly since the 1970s due to automation, lower numbers have “led to increases in stress on both the physical and cognitive demands of the remaining crew” (Lundh, 2014). Hannaford & Van Hassel (2021) concurred with this principle that increased automation does not directly result in the remaining crew having reduced onboard duties. While removing the final tranche of onboard staff is likely to be a phased response, tactical management of workload and the workforce on board must be addressed as part of a transparent change management process (Kooij & Hekkenberg, 2022).

What is commonly referred to, though, is that while the crew may be displaced from the vessel, “human operators would ... still be involved in autonomous ships operations in tasks going from monitoring to remote controlling” (Ramos et al., 2019). As a workload, the remote operators would only react to situations where the onboard systems could not deal with the mundane. This potentially increases the risk that remote operators may be unable to transition “between extremes of workload”, thereby threatening their performance in reacting where the automation fails to perform (Hogg & Ghosh, 2016).

Moving the current iteration of a “seafarer” from on board the ship to shore may have more positive implications regarding a more macro view of the staffing. Multiple reports and warnings have been issued about the shortage of certified personnel, such as officers. The Baltic and International Maritime Council (BIMCO) and the International Chamber of Shipping forecast that in 2021 almost 90,000 more officers would be needed by 2026 to meet the growth requirements predicted in the global shipping industry. Specific concerns relate

to the recruitment of technical officers across all segments and levels, while management-level bridge officer staffing was acute in the tanker and offshore markets (BIMCO & ICS, 2021).

Therefore, if an automated yet increasing workload exists on board, what hope is there for shifting the work to a remote operation centre ashore that only deals with critical incidents? Perhaps the premise of the question is incorrect in terms of shifting work rather than operational competence, but moving “some of the workstations from sea to shore, [this reduces] the risk of the negative impact of hard-working conditions on the safety of the vessel” (Felski & Zwolak, 2020). With the seafarer working ashore, access to resources available to a “regular” shore worker, such as easily accessible occupational health and more ergonomic working conditions, could result in a remote seafarer that can efficiently support multiple ships in a work shift.

### **3.3.4 Operational Efficiency**

Pietrzykowski & Hajduk (2019) highlight the benefit that automation “leads to greater repeatability, enhancement of safety and gradual replacement of people, which will eventually bring economical profits”. In maritime fields, such as the military or emergency response, uncrewed platforms have been used to carry out dirty, dull, or dangerous tasks. Scenarios exist where MASS technology could allow, for example, putting a firefighting tug into a position that would otherwise be inaccessible for a crewed tug (Robert Allan Design, 2018) or naval operations as a force extender (Saballa, 2021). Performing the transport task required of a vessel in a MASS environment may allow different operations.

As seen with the naval operations discussed by Saballa, Unmanned Surface Vessels (USVs) could be deployed by a mother ship to achieve an operational task such as mine clearance or prosecuting a sub-surface contact in Anti-Submarine Warfare (ASW) while keeping the crewed mother ship in a relatively safe area remote from the USV. In merchant shipping, this mother ship concept has been presented by Akbar et al., who concluded in 2021 that the use of tailored autonomous daughter ships to deliver and collect cargo in Norwegian short sea traffic that then tranships to mother ships that make the connection to continental ports such as Rotterdam, could save 11-15% of costs. Operationally, routes can be optimised based on the cargo demand and coordinated with transshipment to and from the mother ships. The most significant difference is that rather than the daughter ships being under positive control from the mother ship, such as a USV to its ASW frigate or minesweeper parent in

the naval domain, managing a mother/ daughter fleet will require shore coordination and costs associated with that shore control centre investment (Akbar et al., 2021).

Operational efficiency is also the ability to have the correct competence on board at any time. This is already “a complicated operation that involves flying a total of more than 100,000 sailors industry-wide around the world every month to connect with ships” (Paris, 2020). The earlier mentioned complication of fatigue and workload is an issue with current crews. Still, with crew members facing extensions to employment contracts on board due to not having a reliever able to join the ships, month-long contracts were extended during the Covid-19 pandemic as crews could not rotate in or out. Remote and performance monitoring through remote means exploded during the pandemic (DNV, 2020). This trend highlighted the marine industry’s willingness to embrace remote technologies. These technologies enable increased equipment availability facilitated by data analysis by shore experts.

### **3.3.5 Cost Reductions**

Autonomous ships could reduce labour and fuel costs, with the potential to have a significant impact on the cost basis for shipping companies. The environmental efficiency section below discusses cost reduction related to fuel due to the interrelation between fuel and emissions.

Regarding labour costs, there is debate on the validity of the assumption that MASS will automatically eliminate costs. Instead, “human elements don’t fade away in MASS, but rather get transferred to the shore” (Yoo & Shan, 2019). Akbar et al. (2021) carried out an in-depth modelling with the Norwegian short sea shipping market to assess the cost-benefit of removing the crew on board and operating entirely autonomously, as they suggest “[t]he next generation of ships in the maritime shipping industry will likely be characterised by full autonomy where ships operate without any crew on board”. In their 2021 study using a short sea container vessel in a case study to establish a recognisable pathway to uncrewed autonomy, Kooij & Hekkenberg (2022) estimated the monthly crewing cost to be €97,800 based on “two complete crews, that each operate the ship for half the year.”

Positing that a “fully autonomous ship, with no monitoring or interference by humans, is not expected to be a reality in the near future” to guarantee the smooth operation of vessels, it will be imperative to have Shore Control Centres (SCC) in place for monitoring purposes (Ramos et al., 2019). While the cost of these is unknown, the ability of the SCCs would

have the capability to monitor multiple ships simultaneously. Such centres are already in operation today, such as the Carnival Corporation network of Fleet Operations Centers that allow “integrated shore teams [to] support... shipboard officers to act quickly” as well as optimising the operational performance of the ship (Kalosh, 2018). Therefore, the “crewing” cost of the SCC would tend towards negligible with enough volume, presenting a significant incentive towards scaling MASS (Akbar et al., 2021). Indeed, it may be that “the combination of human capabilities and experience and autonomous technology can do a better job together than any one of the two could do alone” (Tervo, 2021).

While the operational costs are likely to reduce with no crew on board, the initial investment charge to compensate for no humans on board “since the unmanned vessel needs to operate without any disruption of operations for a specific time, it is not feasible to repair the broken components onboard” (Abaei et al., 2022). Additional equipment is required to support system redundancy, vessel safety and security. Still, an autonomous “ship will only be built if it is economically viable and at least costs the same, or less, than a conventional ship in operation” (Kooij & Hekkenberg, 2022).

### **3.3.6 Environmental Efficiency**

A conventional ship, or an entire shipping company, is exposed to multiple forces on its operations, regulatory or environmental. Pressure on ships to be as efficient as possible, i.e., keeping costs as low as possible while still maximising cargo/ passenger load to achieve the transport task, is immense. While substitution through other transport methods is unlikely for longer-distance logistics, the requirement to reduce energy consumption is a driving force for onboard optimisation. On conventional vessels, this is the direct reduction of fuel consumption. Currently, ships built after 2015 must comply with the IMO Maritime Pollution regulations against the Energy Efficiency Design Index (EEDI), while the entire fleet must comply with the Carbon Intensity Index (CII). Significant research has been put in place with a market available to incorporate “a lot of measures which can be used to improve the energy efficiency of the ships” (Ammar, 2018).

Optimising the entire propulsion system can significantly enhance its operational efficiency. Ships are frequently constructed with unused allowances, which can be improved through adjustments in their lifetime. Other options include the general reduction in energy consumption, including variable speed motors for large consumers on board (e.g., seawater circulation pumps, ventilation fans or HVAC compressors) or augmenting the propulsion



through other means such as wind power or more efficient waste heat recovery from the engines. Operationally, voyage plans can be altered to reduce the speed required in a technique referred to as "slow steaming".

Selecting how to use energy efficiency tools is complicated further by the time window involved. Many ships will take on fuel every two weeks, and with such large fuel tanks, seeing a rate of change in consumption takes time and effort. Not only do fuels worldwide have different specific energy densities, but any change in weather, ship loading or ballasting requirements will show a shift in energy consumption. Therefore, it can be challenging to expect the crew on board to spend part of their working time establishing which energy-saving method works. With their higher sensor count and ability to store data, autonomous ships, or even remote-controlled ships, methodically suggest using ML or AI to extract the necessary information with subsequent decisions made in the most efficient operational profile.

Implementing this sense-decide-act loop multiple times in a voyage is clearly where the benefit of MASS can be used in shipping to optimise the ship's operational performance. Implementing this with existing ships is already plausible, with systems claiming to be available.

MASS may be more fuel efficient than conventional ships where crew habitability and function drive designs. Producing more sleek or slender ships can reduce the energy demand "if there is no crew on board, [as] many constraints of the ship's design can be removed" (Chae et al., 2020). Therefore, a smaller, lighter, and more slippery autonomous ship could carry the same cargo volume as a conventional ship while producing fewer emissions. This could further reduce costs when operating in areas with emission trading schemes.

## 4 Impact on Business Models

Whilst much has been written on the technical and project risks of implementing MASS, the principal research question in this thesis is to investigate the risks and opportunities with autonomous shipping from a business standpoint. The spectrum of explanation of a business model in the literature regarding autonomous shipping can be as simple as "the possibility of using autonomous and remotely operated vessels are also introducing novel or changed transport systems and *business models* [emphasis added] where, e.g. smaller unmanned vessels can be used the last mile bringing cargo from a mother ship to smaller less area-

demanding harbours” (Haugen et al., 2019). This explanation needs to be revised to answer the research proposal. If we cannot define a business model, how can we answer the research question of where would an autonomous ship make sense?

A critical matter is a reframing of the question as Doganova and Eyquem-Renault proposed in 2019, “[t]he question... is not ‘what are business models?’, but ‘what do business models do?’.” When considering a business model as an active device, this frames it in a manner that allows a customer-centric or value-adding purpose for a company. Currently, “[t]here is no consensus concerning the purpose of MASS technology” (The Honourable Company of Master Mariners, 2023). This thesis research mainly focuses on determining the purpose of autonomous shipping. It questions the relevance of investing in autonomous shipping and needs to understand its ultimate objective.

#### **4.1 What is a Business Model?**

While MASS could be deployed for access to new technology, operational cost reduction by eliminating crew, elimination of human error or using a smaller vessel to carry out the same transport task (The Honourable Company of Master Mariners, 2023), knowing how to operate MASS within the way a shipping business operates requires an analysis of the incumbent operational models. Utilising the “what do business models do” approach allows flexibility in choosing a framework to enable further analysis of the MASS application.

Johnson et al. (2008) suggest a four-part business model focussing on a customer value proposition, profit formula, essential resources, and critical processes. Crucially, a successful implementation under their model focussed on gaining a “yes” response to the following four questions:

- Can you nail the job with a focused, compelling customer value proposition?
- Can you devise a model in which all the elements ... work together to get the job done in the most efficient way possible?
- Can you create a new business development process unfettered by the often negative influences of your core business?
- Will the new business model disrupt competitors?

This “constellation” of activities that have been established by Johnson et al. is reflected some years later by Amit & Zott (2012), who also referenced the Apple strategy reinvention in line with the launch of the iPod and its impact on the music downloading ecosystem versus the correlation to the much earlier Gillette “razor and blade” model. They say this makes it harder for the companies to get “wiped out by a new competing innovation that eliminates the need for your product”.

The “razor and blade” business model, in its simplified form, suggests that selling a platform (the razor in this case) cheaply or free would then lock out, or increases the barrier to entry, competition in the aftermarket (disposable blades) where profit could be maximised in a virtual monopoly. While the Gillette history in this is rather more nuanced, the model is used in cases such as the Apple platform and services model, or even “from VCRs and DVD players to video game systems” (Picker, 2011).

Applying shipping models as they stand today against the four questions Johnson et al. proposed helps prepare for analysis with a future autonomous fleet.

## **4.2 Shipping’s Customer Value Proposition**

At its core, shipping provides transport for commercial gain. Unfortunately, a "one size fits all" approach does not initially apply as the variety of cargoes and passenger transport necessitate segmentation of the shipping industry. While the bulk carriage of commodities like ore typically results in ships that are floating warehouses, they are comparatively straightforward in construction when compared to tankers that carry bulk gas cargoes that need onboard reliquification plants to ensure the volatile cargo reaches its destination. During the 1960s, the shipping container revolutionised how goods of various sizes and shapes were transported. This led to the development of container ships, like the Maersk Triple-E class, which are now massive vessels that operate globally. These ships are part of a network that includes smaller carriers that handle the distribution of containers to their final destinations (George, 2013).

This segmentation has allowed shipping companies to be diverse in customer service. However, one defining feature for most ships is to uplift cargo in one place at a determined time, transport that cargo intact (or as intact as possible) and offload in another location within either a window of opportunity or a specific time. This reliability in delivery creates value along the supply chain and underpins the customer value proposition that most of the shipping industry provides.

Several exceptions apply to all naval, coastguard or governmental ships or vessels supporting offshore construction, rigs, windfarms, or survey/ seismic vessels. In such cases, the alternative to providing value in a delivery context is replaced with being available to achieve a job.

In providing clarity to defining its role, shipping is achieving the ship's designed task within an agreed timeframe against the customer's specification at the most profitable price point.

Shipping is an asset-heavy business that has multiple layers of regulation. While the concept of High Seas is still present, various legal instruments come into play when a geographical law of the land is not in force, meaning that all ships have a jurisdiction they must comply with at a minimum. This is the laws issued in the country that a ship is registered in, a so-called "Flag State", as this is the literal flag a ship will fly from its stern. The ship's registered country would then be responsible for matters such as the minimum level of seaworthiness. Additional requirements (and costs) can be levied by the operational areas a ship will trade within. The ports the ship visits are then empowered to conduct inspections as the "Port State" to ensure compliance (Smeele, 2021).

Being asset-heavy, the main costs are managed through capital costs in the investment of a vessel with the operational costs to operate the ship during its lifetime. Further capital investment may be required to continue to trade or where operational expenditure may be reduced. Understanding the generation of cost structures and how to optimise these elements is essential to moving forward on the business model construct.

### Capital Expenditure

Capital expenditure, or Capex, is money spent to increase the capability of a company to generate income or benefits beyond the current financial period. Typically, these are relatively large in the shipping industry when compared to the rest of the company's finances and could include the purchase of high-value assets (e.g., ships) as well as the cost of significant upgrades to existing assets (e.g., mid-life drydocking, modernisation of a cruise ship's interiors & cabins). These assets will depreciate over a defined time.

Ships are bought new from shipyards or traded as used, as cars are sold. Typical pathways for companies to increase their fleet size are:

New buildings: Ordered directly from a shipyard, either to specification or as part of a series of ships the shipyard is building.

Second-hand market: Used ships acquired from ship owners, brokers, or auctions. While typically much lower in cost and quicker, specialist support in inspecting the ship's condition will be needed, and additional maintenance work may be required to suit the ship's specialisation.

Leasing/ charter: Rather than acquiring a ship outright, companies may choose to lease or charter to have the capacity a ship would bring without the need to take on the asset on their books.

The process of acquiring a ship through any of the above is highly complex, may cross multiple legal jurisdictions, and naturally is up for various negotiations.

While the traditional basis of the lowest price has won, the impact of environmental regulations such as the EU European Trading Schemes (ETS) requires the installation of either more equipment or equipment needed to be of a higher specification/ performance to enable the ship a license to operate. According to today's fleet, an extreme example is the emission-producing energy sources ban in the Norwegian Fjords from 2026 (Schlagwein, 2019). To have a "license to operate", ships must be fitted with an energy source that does not produce noxious emissions to enable entrance into the fjords. This requires either installation during the build or retrofitting of the existing fleet to be allowed to operate according to the ship's tasking. Failure to comply could render the investment obsolete at delivery.

### Operational Expenditure

Operational Expenditure (OpEx) is any expense incurred because of a business's need to maintain day-to-day operations (Bonem, 2018, p. 107). The management or executive team monitors the cost of doing business to ensure an organisation performs its fiduciary and business targets as defined by the board or owners.

In terms of ships, autonomy is targeted at reducing the headcount of staff on board and enabling more efficient consumption of energy to achieve the transport of goods or passengers on a defined route, both of which relate to the OpEx for the day-to-day on board. Compared to ships in operation at the formation of the IMO, where the crew were significantly higher in number (as an example, tankers had a staff of 50-60 officers and crew), modern merchant ships, which are highly automated, are consistently below 15-20 persons (Shaw, 2023). This headcount reduction is directly related to the automation of

operational processes within the merchant fleet. Shaw (2023) says, “70-80% of the [onboard] manpower is on maintenance. It's not on operation”.

### **4.3 Start-up to Market Leader**

Defining a start-up is more complex than one would imagine due to the ambiguity of the use context and where it would be defined. Generally, a start-up is seen as a newly established company, typically in an early stage of operation, developing a new product or service to market. With a high growth potential, start-ups typically deploy technology to drive an innovative business model. While generally associated with technology where companies like Amazon, Google, Uber, and Tinder upended their respective sectors, the term can be applied to any industry. Funding sources for start-ups have been through venture capitalists, angel investors or crowdfunding, and the goal is to scale and grow rapidly. This infers a high degree of risk-taking with a nimble team in a culture of rapid failure and learning, but it is a straightforward definition.

Two cases are of interest where a start-up has become the market leader, and a brief glimpse into Amazon and Uber is considered. While other companies also emerged, Amazon and Uber were selected due to some parallels to the shipping business that, with some synthesis, could show a path to autonomous shipping as a business.

What started as a book delivery service has become a logistical template for the consumer market. Amazon focuses on faster and cheaper delivery to customers by deploying technology, innovation, and scale to realise efficiencies across its operations and reduce costs compared to the market leaders of the time, such as FedEx, UPS, the US Postal Service and DHL (Klaus, 2013).

Whereas the incumbents relied on agents to complete the necessary paperwork and operated a hub and spoke network, as well as having to incorporate local sales taxes, Amazon operates various facilities globally that are now highly automated with robotics to speed up its processes with a reduction in errors. Further efficiencies are gained with data and AI/ ML analytics to manage inventory by predicting demand with increasing accuracy. From a consumer point of view, Amazon's fast delivery capability at a reasonable price (in some geographies, same-day or two-day and at no cost to the consumer) forced competitors to react to compete.

Rather than completely ring-fencing its services, Amazon diversified with online and logistic services for third parties (Ritala et al., 2014), allowing them to access Amazon's infrastructure, enabling smaller sellers to access a more extensive customer base while removing the ability for that seller to use anyone other than Amazon for delivery. Further innovations in delivery methods, such as lockers to allow on-demand pick up of goods to delivery drones, aim to improve the customer experience (Wells et al., 2018). This increasing speed of delivery to a customer is also seen in the international shipping market, with the increasing volumes of cargo attributed to this Amazon effect and e-commerce (UNCTAD, 2022).

In another disruption to customers based on technology, Uber was founded in 2009 by a pair of technologist entrepreneurs. Realising that conventional taxis needed to be hailed on the street or ordered one by phone to a dispatcher, Uber leveraged the increasing connectivity available to people to enable a ride-hailing service through a smartphone app. While initially conceived as a high-end chauffeur service, Uber pivoted their market towards low-cost options to widen the available customer base (Cartwright, 2021).

While chauffeur services have been present in San Francisco since the beginning of the 20<sup>th</sup> century, the taxi industry's deregulation saw business changes during the post-Second World War period (Dubal, 2017). What has underwritten market penetration is the ability of Uber to anticipate demand when dynamic pricing is used to encourage additional drivers to be available. The platform started with drivers being contractors rather than employees, although this is facing pressure in different jurisdictions with their employment status as contractors or partners being challenged (Aslam & Woodcock, 2020)

Additional controversy has been courted by "traditional" taxi drivers. These chauffeurs may have had to be licensed within the cities where they ply their trade, and consumer regulations are consequently bypassed. However, the service continues to operate in over 10000 cities, with services diversifying beyond ridesharing, such as delivery services (Uber, 2018). While disrupting the traditional hailing or phoning model of taxis, the technology basis has also been incorporated into the traditional model, where deregulation of the taxi industry has allowed this to happen.

#### **4.4 Current Shipping Business Models**

While the methods to acquire a ship into an owner's fleet were discussed briefly in **Error! Reference source not found.**, once the ship is in the fleet, its use can vary depending on the

needs of the charterer (the party paying to use the ship) as well as the type of ship, presented in a simplified view in Table 1:

**Table 1**

*Forms of Charter and Responsibilities*

	Voyage Charter	Time Charter	Bareboat Charter
Scope	From one port to another with a predetermined cargo	Ranges from several months to several years	As required
Shipowner Responsibility	Controls ship, crew, OpEx (e.g., fuel, port charges)	Controls ship & crew only	Hull only
Charterer Responsibility	Pays Shipowner for the use of ship and crew	A fixed daily/ monthly rate, also responsible for all fuel, port charges and other OpEx	The entire operation, including crew, maintenance, and insurance, as well as a fixed rate for the ship's use

Contract of Affreightments are agreements between the ship owner and charterer to transport a set amount of cargo over a specified period. The shipowner will provide the ship and crew while the charterer covers loading and unloading. However, further contractual agreements can and do exist to satisfy specific needs.

As part of a risk management strategy, the various stakeholders in the shipping chain take out insurance or underwriting to mitigate losses or damages during and potentially after the voyage. These will include physical damage, partial or total loss of the vessel or the cargo, and any third-party liability to which the ship may be exposed. Additional insurance that covers specific risks in certain trades may be taken up, such as piracy, war, and terrorism.

While the costs can vary just as insurance costs ashore, the liability costs may be too high or uncertain for a single underwriter. This high cost vs uncertainty led to the development of Protection and Indemnity Clubs, where shipowners would band together to cover any liabilities arising from liability, such as personal injury or property damage as well as pollution and environmental damage.



Another quirk of marine insurance is the “General Average Insurance” that is taken out should the cargo be sacrificed to save the ship and its crew. The assignment of liability is crucial to all insurance policies in the current marine regulatory framework. The assumption is that liability can be apportioned on the basis that ships are crewed according to the relevant maritime regulations. Where does the liability sit with an uncrewed, autonomous ship?

## **5 Discussion**

### **5.1 Interviews**

The interviews were conducted over Microsoft Teams, allowing recording and subsequent transcription utilising the questions outlined in 2.2 above.

As outlined, the number of interviews carried out was significantly smaller than any survey via electronic forms. However, having the time and scope to explore the challenges and opportunities arising from MASS, or even using autonomous technologies, proved valuable with the interview subjects themselves. A summary of responses by the respondents to each question is submitted in Appendix 1, while the analysis of the response to each question by the interviewees as a cohort is in paragraph 5.2 below.

#### **5.1.1 Interviewee #1**

During the interview, Interviewee #1 stressed that unmanned ships are currently impractical and discussed the potential use of autonomous systems for specific ship tasks. They emphasised the importance of defining terminology to avoid confusion and clearly distinguished between autonomous and automatic ships. As per the interviewee, an autonomous ship is a problem-solving function, while an automatic ship is a control function.

The interview also covered different levels of autonomy and how it is removed from crewing, including altering speed and avoiding obstacles. The interviewee also acknowledged the challenges of implementing autonomous ships, such as the requirement for a stepwise approach to developing and integrating autonomous technology in ship designs. They recommended that business models for autonomous ships could resemble today's bareboat charters, making it easier for new entrants like Amazon to join the market.

It is imperative to recognise that the concept of autonomous shipping does not function as an independent business model. Instead, there is an increasing need for more sophisticated

autonomous technology to tackle various business obstacles. One such example is Japan's ageing population and geographical constraints, which make sea traffic a crucial factor in ensuring the seamless operation of society. However, determining the accountability for uncrewed vessels in the shipping industry still demands further setting out from UNCLOS.

### **5.1.2 Interviewee #2**

The second interviewee evaluates ship performance using metrics like rate of turn and vessel response. The company they worked for owned the ships and took responsibility for all operational aspects. The impact of onboard staff on fleet operations is explored because the crew is required to be on board most of the time.

According to the interviewee, MASS must have advanced dynamic positioning systems for navigation and manoeuvrability. Fleet managers can optimise fleet operations by utilising technologies considering fuel efficiency, consumption rates, and operational efficiency. Integrating autonomous technology and DP systems enhances operational capabilities while reducing the need for physical presence at sea for specific tasks. Autonomy in shipping can solve problems related to reducing physical presence at sea for specific tasks. Communicating the benefits of autonomous technology to all parties involved is essential.

The interviewee suggests implementing partially autonomous systems as a comfortable first step that allows crew members to monitor and control the ship remotely from land. The concept of B0, supporting rather than replacing the crew, is also proposed as an initial approach. This interviewee also cited the ongoing case in Japan, where autonomous technology could be widely adopted in regions with ageing populations and crucial inter-island transportation needs.

### **5.1.3 Interviewee #3**

This respondent started the interview with the critical point that passenger ships may be an exception to the shipping industry, given that they may not lend themselves to autonomous operations due to passenger muster lists. Key performance indicators (KPIs) are discussed, such as fuel efficiency, safety data, and passenger feedback. The interviewee also discusses challenges related to gathering data on shipping operations and data siloing within departments. Navigation incidents and environmental procedures are also discussed, including the challenges of integrating deck and engine teams and the impact of the pandemic on social dynamics onboard ships.

The discussion also covers the ferry industry and the difficulty of introducing new processes like Bridge Resource Management (BRM) to a long-standing business model. Their company operates a business-to-consumer (BTC) model primarily.

Training and leadership skills for captains were discussed. The potential for autonomy in cruise ships is also explored, focusing on areas where human error is prevalent and systems development to ensure compliance with regulations. The liability of autonomous technology is also discussed, with the captain ultimately responsible for ensuring the technology is performing correctly.

Overall, data-related challenges and navigation incidents are potential business opportunities for autonomy. The discussion also touches on the importance of leadership and training for captains and the potential liability issues related to autonomous technology.

#### **5.1.4 Interviewee #4**

Interviewee #4 works for a company that operates in the European shortsea "Roll On-Roll Off passenger" sector. The company has multiple vessel ownership models, including leasing ships from its parent company, owning them outright on some routes and chartering them on various other routes. While fuel economy is used to evaluate ship performance, a more comprehensive performance metric could be obtained by considering berth-to-berth times and tug usage, but this still needs to be monitored. Real-time engine usage and fuel efficiency monitoring systems are currently being implemented.

The company has optimised ship utilisation through freight contracts and agreements with competitors. Onboard staff, including service, cleanliness, food, and friendly staff, greatly influence customer satisfaction with deploying the Net Promotor Score (NPS) system.

While autonomy in Maritime Autonomous Surface Ships (MASS) offers potential efficiency and cost reduction benefits, concerns exist over system malfunctions and the need for more qualified seafarers. Different ship types experience varying impacts, but autonomy can help tackle challenges while retaining some crewing elements. Safety, compliance, and human involvement in certain ship operations are crucial and emphasised.

Exploring different ship types for autonomy and possible approaches to autonomous shipping includes dedicated lanes and remote support. Bulk cargo ships are an appropriate starting point for autonomy, but concerns about pilot safety and shipyards' compliance issues are noted.

### 5.1.5 Interviewee #5

The researcher interviewed someone with military experience to gain a fresh perspective, as most interviewees were from the merchant side. The fifth interviewee primarily operates in the Navy, mainly in the Baltic region, with occasional assignments in the Atlantic zone.

The Navy's primary responsibility is to maintain the country's territorial waters' integrity, functioning as a separate business entity within the military. They provide seaborne naval forces and their capabilities, with ultimate responsibility held by the Chief of the Defence Force, requiring approval and budgeting from higher authorities. Ownership and chartering of ships were discussed, with government-owned vessels being typical, while charters were used for specialised ships within the national government's financial resources. Although financing may come from different departments within the government, ownership ultimately remains with the state. Additional efforts to reduce upkeep costs are promoted through collaboration and standardisation in using parts and processes. Personnel with vessel experience have a more significant say in personnel decisions. Although input from those on board is considered, significant decisions may require approval from higher authorities, potentially resulting in delays due to governmental bureaucracies.

During the interview, the respondent discussed the impact the implementation of MASS could have on onboard culture. They recognised the benefits of autonomy, including improved safety by preventing accidents, and acknowledged potential challenges such as complacency and overreliance on technology. The interviewee presented the importance of informing crews about relevant information and alerts to prevent accidents or collisions and stressing the need for people of all ages to accept and understand autonomous technology. They then explained that fully autonomous ships should be capable of making fundamental decisions and completing tasks like avoiding collisions. In the future, they may even be able to provide necessary supplies in the ocean or other military taskings. MASS is a valuable tool in achieving this, allowing a vessel to operate at sea without relying on a crew while still being able to provide necessary supplies.

In the interview's closing, Interviewee #5 stated that the first step towards adopting autonomous technology should be improving situational awareness and reaction times. They recommended using autonomous systems to enhance lookout capabilities and provide a 360-degree view to enhance safety and reduce crew fatigue. The interview also discussed the potential benefits of autonomy, the significance of proper implementation and acceptance,

and the need for continuous advancements in autonomous technology to overcome maritime challenges.

## 5.2 Interview Analysis

This section reviews the responses from the interviewees. The first question regarding what sector the interviewee operated in is excluded from this analysis as it was asked to provide context on the remaining questions.

### **What metrics do you use to consider if a ship is performing well or underperforming?**

While some interviewees focused on the financial aspect, including shareholder value and cost management, one interviewee made a crucial observation. They pointed out that maximising asset performance may come at the cost of the crew's well-being. In addition, interviewees discussed specific operational metrics utilised to evaluate ship performance, such as fuel economy, fuel efficiency, rate of turn, responsiveness of equipment, and punctuality. These metrics aid in measuring the ship's efficiency and effectiveness in its operations. Lastly, interviewees highlighted the importance of safety data, incident data, and passenger feedback as indicators of ship performance. Regular incidents and negative feedback indicate underperformance, which may require intervention or coaching to address the underlying issues.

Based on the interviews, more metrics are needed to evaluate ship performance. Some interviewees have cited various metrics and performance indicators that they deem significant. In contrast, one interviewee has specifically emphasised the importance of customer service and measures like Net Promoter Score in assessing ship performance. This perspective highlights the customer experience as a crucial factor that may differ from the metrics used by others, such as fuel cost or crew performance. Indeed, this is where the differences arise in the plethora of ships in operation. While onboard passenger responses are essential in segments with passengers, most ships in operation are cargo-carrying. Therefore, energy costs per cargo carried and punctuality will likely be the most critical metric. Crew satisfaction rose as one aspect that is not commonly discussed, particularly given the impact that crew have on the performance of a ship.

### **Do you own your ships directly, or are you chartering? Do you trade the ships yourself, or are they chartered out?**

During the interviews, it was discovered that some individuals owned their ships while others worked for ship-owning companies. There was also a mention of a ship owned by a

single person. Chartering was also discussed, with several interviewees mentioning different durations, such as long-term and voyage charters. Chartering can involve liner traffic, spot markets, or bareboat charters. One interviewee stated that liability does not matter for charterers, while another emphasised the importance of considering the party's track record in a bareboat charter.

During the interviews, one person said their company handles everything in-house and prefers direct ownership. Meanwhile, another interviewee mentioned that their fleet of ships is chartered on a bareboat basis from a corporate owner, indicating a different approach. Military vessels have separate financing from different government departments. The main themes that emerged were ownership and chartering, with differing opinions on liability and involvement in ship operations. Some interviewees suggested their organisations preferred direct ownership, while others favoured chartering.

**What is your business, and what is your business model? Who are your customers? What impact do on board staff have on fleet operations?**

The fundamental business model revolves around cargo transportation, with interviewees acknowledging its central role in the industry. Although business drivers and liability concerns may change, the need for cargo space remains constant, even in the case of passenger ferries, where Roll On- Roll Off cargo is a crucial determinant in scheduling.

The dominant market in the shipping industry is business-to-business (B2B), while business-to-consumer (B2C) interactions represent a significantly smaller percentage. The importance of aligning cruise itineraries with customers' home bases was emphasised, highlighting a customer-centric approach in the cruise sector which is an outlier in the broader maritime industry.

The interviewees unanimously recognised the crucial role of onboard staff in fleet operations, particularly in adhering to labour laws. Strict compliance with these regulations is essential to avoid strikes or union involvement. However, optimising staff utilisation within the constraints of labour laws was acknowledged as a challenge due to time limitations. The captain's authority and leadership were also unanimously acknowledged as central to current fleet operations, with the captain holding ultimate decision-making power. The importance of accountability and leadership qualities in the captain's role was emphasised, suggesting room for improvement.

Operational priorities varied among interviewees, with fuel economy and schedule adherence being commonly mentioned. However, the integrity of territorial waters emerged as a primary task for one interviewee, indicating potential differences in emphasis and priorities across sectors within the shipping industry. Collaborative relationships with hauliers and agreements with competitors were highlighted, emphasising the importance of collaboration for minimising costs and ensuring operational efficiency. However, competition and the differentiation of rates based on commitment levels contribute to the complexity of the business model.

**How do you think MASS will impact your operations at the ship level/ fleet level/ shore operations? How do you see the impact on the total cost of ownership of a ship?**

There are differing opinions on the effect of autonomy and automation on the total cost of ownership. One interviewee is sceptical about saving salaries, stating that it has yet to be a significant consideration in discussions about autonomy and automation. However, others acknowledge the potential for saving operational expenditure (OpEx) through automation. These varying views suggest a difference in priorities, with some prioritising cost savings and others prioritising crew salaries and operational efficiency.

Conflicting views also arise regarding crew accommodations. Some interviewees believe that operational ships will still need accommodation facilities, while others envision unmanned or minimally manned ships that eliminate the need for such amenities. This disagreement indicates differing views on how autonomy can replace traditional crewed vessels.

The ownership and monitoring of autonomous ships are also topics that need to be made public. One interviewee suggests that companies may lease out monitoring services, while another theorises the emergence of pseudo-ship management companies. These perspectives highlight uncertainty regarding the future ownership and operational models of autonomous vessels. Furthermore, one interviewee emphasises the importance of situational awareness and force protection in autonomous vessels. They argue that maintaining a high level of situational awareness is crucial, conflicting with reducing crew size to a minimum. Improving situational awareness will require advanced sensor systems, which may, in turn, require more crew with a specialised skill set.

While there is general acceptance of the benefits of autonomy and automation, concerns about crew well-being, organisational changes, and balancing cost savings and operational

efficiency remain. These varying viewpoints underscore the ongoing debates and uncertainties surrounding implementing MASS in the maritime industry.

**What problems will autonomy solve? Do you see further issues or potential unintended consequences?**

During interviews, a significant theme was the potential for autonomous ships to increase safety and efficiency in maritime operations. Interviewees discussed scenarios where autonomous or remotely operated vessels could reduce risks to human life, particularly in firefighting operations in hazardous environments. Furthermore, concerns about crew shortages in domestic traffic regions led to conversations about utilising autonomous systems to optimise port operations, cargo handling, and open-sea navigation.

Another common theme involved the challenges associated with liability and responsibility in autonomous ship operations. Interviewees had differing opinions on the role of captains and officers in decision-making, with some emphasising their continued involvement and others suggesting that responsibility could shift to technology providers. It was seen as crucial to define ship ownership and establish clear legal frameworks to ensure accountability in the context of autonomous ships operating without a representative on board.

The interviewees also recognised the technological superiority of autonomous systems compared to humans. They highlighted advantages such as optimal control decisions, improved fuel efficiency, and the ability to adapt to changing environments through advanced sensors and computing capabilities. This shared perspective emphasised the potential for autonomous ships to outperform human-operated vessels in specific tasks and improve overall performance.

Additionally, interviewees acknowledged that integrating autonomous systems would require training and skill development for seafarers and staff members. While technology offered exciting opportunities, concerns about the learning curve of adopting autonomous ships were raised. Ensuring adequate support and resources during the transition is vital.

During interviews, concerns were expressed about the possible unintended consequences of implementing autonomous ships, such as malfunctions, sensor failures, accidents, collisions, and pollution. Others highlighted the importance of implementing robust security measures and conducting comprehensive risk assessments to mitigate these risks. These conflicting



perspectives emphasised the need to address potential drawbacks and ensure the safe and responsible use of autonomous technology.

In addition, some interviewees expressed concerns about accepting and adopting autonomous ships. They feared it might lead to crew displacement and adversely impact seafaring. They urged consideration of the human element and potential consequences for maritime employment. However, autonomy proponents believed it necessary to address crew shortages and sustain maritime operations. They stressed the potential benefits and the need for transparent communication, collaborative efforts, and addressing the concerns of all stakeholders to gain acceptance.

Finally, there was a difference of opinion on autonomous ships' desired degree of autonomy. Some believed significant autonomy was necessary, including the possibility of shutting down systems automatically or extending autonomous control to various areas of a ship. Others preferred limited applications, focusing on specific functions such as lookout duties or maintenance operations. Striking the right balance between human control and automated systems was identified as a critical consideration in autonomous ship operations.

While there was agreement on the potential benefits of enhanced safety, efficiency, and technological superiority, conflicting viewpoints arose regarding liability, unintended consequences, acceptance, and the desired degree of autonomy should MASS be deployed.

### **5.3 Summarising the interviews**

At a high level, the interview responses can be summarised as follows:

- Metrics for ship performance: Financial indicators, fuel economy, punctuality, safety data.
- Ownership and chartering: Varying ownership models, including direct ownership and chartering on different terms, although cargo shippers will likely be more concerned if the cargo is delayed.
- Impact of onboard staff: Crucial role in fleet operations, labour law compliance, captain's authority, and leadership. Change management must be engaged at a detailed level for existing companies.

- Impact of autonomy: Potential benefits in safety, efficiency, and technological superiority, concerns about liability, unintended consequences, crew displacement, and desired degree of autonomy.

Although brief, these bullet points highlight the themes discussed by the interviewees.

#### **5.4 Future development of interviews**

The questions were developed after the literature review to temper the academic and technical aspects of the literature with real-world operational experience. However, the respondent count must be higher to consider the interview input as a representative sample of the maritime industry. At the same time, the proportion of interviewees who have worked or currently work in passenger-centric segments (i.e. Ferries or Cruise) may have skewed the focus more.

In terms of improving the process, the analysis would need to be carried out specifically within one company for several reasons. Firstly, the confidentiality limitations on the interviewees by their employers meant that the discussions were required to be reasonably generic. Secondly, the drivers one interviewee alluded to will differ from one company to the next and from one segment to the next.

Questions for further interviews will need to be more precise for deeper insights. For example, the interviewees interpreted the question about “metrics” differently. In one case, the respondent assumed that the response must be related to fuel consumption due to the researcher’s previous role as a marine engineer on board. Simplifying the questions, adapting, or altering the questions to “mirror” the language as appropriate to achieve the necessary responses towards the research question (Legard et al., 2003, p. 155)

If the approach is taken to remove the regulatory aspects and give freedom to the candidates, then a detailed analysis, such as the SWOT analysis in the next segment, could be carried out, allowing a commercial analysis of the business independently of today’s legal and liability aspects to explore the realm of the possible.

#### **5.5 SWOT Analysis**

SWOT analysis has been used in business organisations since the 1970s following a development of long-range planning where “it was designed and used between 1965-1972”

by Robert Franklin Stewart, a psychologist and industrial engineer working at Lockheed Aircraft Corporation (Puyt et al., 2020).

Typically, SWOT analyses are conducted within a brainstorming session to utilise a broad base of experiences and knowledge that a group can produce. The knowledge collected from literature and interviews provided this knowledge for this research. Further refinement is possible when carrying out SWOT by assigning the internal strengths and weaknesses vs external opportunities and threats (Helms & Nixon, 2010). The analysis is done at such a macro level that diving into a commercially sensitive area would only be appropriate with the patronage of an interested party—however, the table below attempts to capture this 2 x 2 format as an example. Further explanations, based on what has been researched, elaborate on these points afterwards.

The SWOT methodology has been criticised for needing more direct outputs when considering strategic views instead of being used in the business sense for producing lists that lack weighting in the factors and not providing a path toward any implementation phase (Hill & Westbrook, 1997). However, for this research, where just identifying the whys and why-nots of MASS, the simplistic structure shown in

Table 2 provides a clear view for most laypersons within the marine industry concerning autonomous ships.

**Table 2**

*SWOT Analysis table*

<p><b><u>Strengths</u></b></p> <p>Increased safety Improved efficiency Reduced costs Environmental benefits</p>	<p><b><u>Weaknesses</u></b></p> <p>Cybersecurity risks Uncertainty around regulations Workforce displacement Limited experience with autonomous ships</p>
<p><b><u>Opportunities</u></b></p> <p>Expansion of shipping operations Development of new business models Collaboration and innovation</p>	<p><b><u>Threats</u></b></p> <p>Regulatory barriers Competition and market uncertainty Technical challenges Public perception and acceptance</p>

Strengths:

Autonomous ships offer numerous benefits, such as enhanced safety by eliminating the need for onboard crew and reducing the potential for human error and fatalities. Furthermore, they can operate at sea for a more extended period, which can significantly increase the efficiency of shipping operations, resulting in cost reductions due to lower crew costs and better fuel efficiency. Autonomous ships could play a vital role in reducing the environmental impact of shipping by consuming less fuel and emitting fewer pollutants or potentially opening up new machinery configurations due to less energy-intensive voyage planning with lower speed demands.

#### Weaknesses:

Autonomous ships are currently facing a variety of challenges that require attention. A significant concern is the potential vulnerability of these ships to cyber-attacks, which are caused by the use of sensors, AI, and computer networks. This vulnerability can risk the ship's and its cargo's safety. Additionally, a lack of a clear regulatory framework for autonomous ships creates uncertainty and problems for all involved parties. Another issue concerns the social and economic implications of eliminating onboard crew, which would lead to job losses and other impacts. Lastly, the technology for autonomous ships is still developing, and more real-world experience is necessary to ensure their safe and effective use.

#### Opportunities:

Autonomous ships present a promising solution for shipping companies looking to broaden their reach and ramp up their shipment frequency. This innovative technology has the potential to unlock fresh business models and opportunities for all stakeholders in the shipping industry.

#### Threats:

Before autonomous ships can become widely adopted, several threats must be addressed. The evolving regulatory framework is one of the biggest hurdles, as obtaining necessary approvals and certifications may prove difficult. Furthermore, introducing autonomous ships could create competition and market uncertainty for existing players in the shipping industry. Technical challenges such as reliable communication networks and navigation systems must also be tackled. Finally, public concerns regarding the safety and security of autonomous ships may impact their adoption and use, making public perception and acceptance a crucial factor to consider.

## 5.6 Analysis

From a business standpoint, the business model concept is crucial in assessing the potential for MASS. Johnson et al.'s four-part business model, which includes customer value proposition, profit formula, essential resources, and critical processes, provides a framework for analysing the potential for MASS. It is important to answer "yes" to these four questions to create a viable business model for autonomous shipping. The customer value proposition in shipping is primarily transport for commercial gain, and achieving the ship's designed task within an agreed timeframe against the customer's specification at the most profitable price point is crucial.

Successful start-up strategies, such as those employed by Amazon and Uber, can provide potential blueprints for the shipping industry to transition to autonomous shipping as a viable business model. However, the shipping industry is a consolidated market with high barriers to entry due to the complex regulatory framework and economies of scale that larger fleets offer. These barriers may make it challenging for smaller companies to transition to autonomous shipping.

Understanding the incumbent forms of operations, such as charters and the responsibility assigned to the parties, will be a defining part of MASS usage. While insurance for autonomous ships already exists (The Shipowners' Club, 2018), questions will arise quickly on the assignment of liability, particularly in the use of the ship and its associated systems. Insurance is important in mitigating losses and damages during voyages, and developing Protection and Indemnity Clubs as a means for shipowners to cover liabilities will remain the same in an autonomous ship.

The challenges associated with decoupling the operation of a ship from onboard crewing levels, such as regulatory and human factors, highlight the need for regulations to govern autonomous shipping. The deployment of Autonomous Ships will have to vary depending on the type of surface ship involved. For bulk cargo vessels where speed is not critical, the load is relatively stable, and of low value, uncrewed MASS could provide an attractive opportunity for bareboat charters for companies such as Glencore. At the other end of the spectrum, passenger vessels provide challenges for uncrewed vessels regarding onboard resourcing for crowd control, muster stations and evacuation requirements. Therefore, it seems reasonable that should MASS be permitted to trade internationally, it would be with a hybrid industry rather than one entirely made up of uncrewed ships.

## 6 Conclusion

The potential for Maritime Autonomous Surface Ships (MASS) to revolutionise the shipping industry has been discussed for several years. Several arguments have been made, particularly in removing crew from dangerous, dull or dirty operations. Despite the remarkable strides made in autonomous technology, there remains a critical area that requires careful examination: the business model for MASS. This element is essential to unlocking the complete potential of autonomous shipping and confronting the obstacles that come with it.

Regarding the first research question, “what are the risks and opportunities with autonomous shipping”, this paper has discussed the risks and opportunities associated with autonomous shipping in several aspects. The potential benefits of MASS, such as increased operational efficiency, reduced labour costs, and enhanced safety due to the removal of crew from dangerous or dull operations, have been discussed. Moreover, challenges such as regulatory issues, human factors, robust risk management practices, and liability concerns will need to be addressed in any business venture involving MASS. One interviewee presented a compelling argument for uncrewed autonomous ships in specific sectors, like heavy lift vessels or bulk carriers, where the presence of human crew might expose them to a higher level of danger where cargo could sink ships just by their movement. This underscores the safety advantages of autonomous operations in select segments.

The second research question asked “is it possible to create a business model for autonomous shipping?” Further detailed consideration is required in the customer value proposition, potential implementation of start-up strategies on a bareboat charter basis, regulatory compliance, and appropriate risk management. As alluded to in the interviews, developing business models for autonomous ships may be the wrong approach. Identifying key drivers for why shipping in its current form is inadequate may provide a more sustainable response to specific markets, such as Japan, where geography and demographics are hostile to the incumbent business model.

The scope of the research presented needs which should be narrower and attempt to answer the question from a global perspective although where the business case may be resolved is the short distance, coastal cargo traffic. This allows individual countries to regulate and designate particular areas for MASS operations, such as seen with *Yara Birkeland* in Norway. An alternative prism to consider is to carry out a similar study within the confines of a shipping company that may want to operate internationally and resource it appropriately

with R&D and Business Development departments having appropriate responsibility in such a case study.

The liability of uncrewed, autonomous ships is a crucial question that suggests an area that may require further research to ensure that regulations and insurance practices keep pace with advances in autonomous shipping technology.

In conclusion, the potential for MASS as a viable business model is significant. Still, it will require careful consideration of various factors, including customer value proposition, successful start-up strategies, regulatory frameworks, and risk management practices. However, as Bainbridge outlined in her 1983 Ironies of Automation paper, “the final irony is that it is the most successful automated systems with the rare need for manual intervention which may need the greatest investment in operator training”. The ability to monitor autonomous vessels in their voyage will be essential to enable humans to take control, even remotely, when needed and compensate for autonomous systems that require creative solutions to unprogrammed challenges.

At least with ships still being built to current standards over the next ten years, at a minimum, humans will be required for seafaring trade to occur for at least the next fifty years. Their location will vary depending on the trade, legislative priorities, and evolving connectivity.

## **7 Further research**

In summary, the semi-structured interview questions utilised in this study were developed based on an extensive literature review and existing theories. This methodology ensured that the questions were not solely derived from personal judgment. The interview questions delved into established topics and explored underexplored or contested areas while minimising potential researcher bias in answering the research questions. In retrospect, this approach favours a Delphi study because it concerns expert opinion and works towards a consensus opinion on the future. The study format is attributed to the RAND Corporation, which aims “to obtain the most reliable consensus of opinion of a group of experts” (Dalkey & Helmer, 1963).

In the Delphi Study, it is not the volume of participants but rather the level of expertise. As Pickard (2013) wrote, “it is better to have fewer members but retain the expert integrity of the panel.” It was in this spirit that restricting the number of interviewees in this research to those who have commanded merchant ships in different ship types, who still work in the

maritime sector, and who have an understanding of MASS at some level. Rather than using written feedback in the most authentic sense, interviews have been transcribed, and a narrative analysis has been presented back to them. The negative aspect of the Delphi study is the “level of commitment from research participants” (Pickard, 2013, p. 155), which prohibited the ability to have multiple rounds with the participants due to their restricted availability for this research. Therefore, the interviews aimed to validate the research questions and explore industry requirements and pressures for adopting autonomous technology. To be able to implement and improve the validity of the research carried out, it is necessary to work within a shipping organisation to maintain confidentiality and commercial advantage.

The field of MASS has now developed at an increased rate since the inception of this research. This is indicated by the sudden jump in published work and conference proceedings after 2020 in the databases used for this research. This increase can be explained by the IMO's completion of the Regulatory Scoping Exercise in May 2021, which was delayed due to the COVID-19 pandemic restricting the Assembly's gathering in 2020. The acceptance of the RSE moved the topic of MASS into the Committees, which will generate more research in the field. It is, therefore, quite likely that the literature review undertaken in this research will become rapidly redundant as the volume of research increases, making assumptions in this paper redundant.

One area that urgently needs attention is the potential for company alliances, like those in the passenger aviation market. These alliances can enable the sharing of vessel space for time-sensitive cargo, collaborative research and development, and shared infrastructure such as shore control centres. It is important to note that more investigation is necessary in this area, as it could also be comparable to a virtual crewing agency model.

Another critical area for investigation is the future of marine pilots. With the emergence of autonomous vessel technology, there is a growing interest in autonomous or remotely piloted ships. It is crucial to understand the role of marine pilots in this new era, the potential benefits and challenges, and the safety considerations associated with their presence or absence. It is also essential to explore regulatory frameworks to ensure safety and efficiency.

Furthermore, comprehending the mechanisms for securing and releasing ships at berths is vital. Although auto-mooring technology exists, it is not widely available. Researching innovative technologies, practices, and safety measures related to securing and releasing



ships will significantly contribute to safer and more efficient port operations. Urgent action is required to ensure that our ports are safe and efficient.

Lastly, at some level, some degree of standardisation of MASS will be needed to facilitate interfacing between shore and ship. This area requires further research, as it will enhance our understanding of evolving ship handling and port infrastructure requirements, contributing to safer and more efficient maritime operations.

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## Appendix 1      Samples of interview responses

This appendix attempts to capture the essence of the interviews conducted as part of the research. They are not provided in any way to be a complete record of the interviews. The quotes are also selected to preserve the anonymity of the participants.

### 1.1 What sector do you operate in, and what are the geographical areas of operation?

Interviewee #1	Interviewee #2	Interviewee #3	Interviewee #4	Interviewee #5
<p>"Everywhere and everything else except passenger vessels and tankers."</p> <p>"My last 10 years was either Chief Officer or Captain"</p>	Deck officer onboard ferries and icebreakers, and an auditor	Cruise industry in worldwide operations	Operates Ropax ferries on short sea European routes. He has previous experience as a marine pilot.	Naval vessels "mainly in the Baltics... sometimes to the Atlantic"



## 1.2 What metrics do you use to consider if a ship is performing well or underperforming?

Interviewee #1	Interviewee #2	Interviewee #3	Interviewee #4	Interviewee #5
<p>"If you're looking from the company point of view, which is which I've also done to, to sit at the office and also being a Charterer is that asset performing at its maximum, which might be very good for the shareholders but can be a really ... raw deal for the crew on board."</p> <p>"For the large vessels, you talk about the part of the crew cost is somewhere between one and 2%..... Where you see the highest amount of crew cost in the OpEx is in the passenger segment. Which is probably going to be by far the last ones that are going to be without crew. So, the drivers have to come from somewhere else than cost."</p>	<p>"When you drive the vessel, you see that is it oversteering or understeering? You expect a 200 metre [ropax] to have a certain rate of turn and at the time when you touch the lever that something happens. And if it that is lacking, the ramps are too slow or something, then you try to fix those ramps according to the expected response to what you have had earlier. And of course, the ramps can be too high, because then usually the ramps are defined by the engine manufacturers and stuff, so you basically have a feeling of a good vessel. According to those metrics."</p>	<p>"covers some things like Fuel economy, fuel efficiency, things like that as well, and looking at those areas. But then we've also, I mean when you talk about performing or underperforming, we've also got areas that we look at in terms of performance such as Instant data and our and our own KPIs and you know those sorts of it's a bigger subject matter, so we're looking at safety data, incident data and then also you know the feedback they get from passengers."</p> <p>"So, if we're seeing trends on ships where they're having regular incidents, then obviously there's an area of concern there. So that would be a sort of an</p>	<p>"There's very little metrics used ... at all at the moment."</p> <p>"Customer interfacing is one of our biggest areas that we're scored on. We've got a thing which is called Net Promoter Score and we monitor that very closely to see how we're delivering good customer service or not."</p> <p>"For me, I look at punctuality, fuel cost and then how the crew perform and that's wide-ranging from, across the three departments. But again, you know you can tell very quickly which masters are signed up to let's try to keep the ship on time and save fuel at the same time. Whereas those who can run on time all the time, but they use 4 engines.</p>	<p>Not answered.</p>

		<p>underperforming ship. Then we might send out someone from our department to go and sort of try and see what the problem is and coach some of it, so that that's you know, where we see underperformance, we get."</p>	<p>Which is the easy way of doing it."</p>	
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### 1.3 Do you own your ships directly, or are you chartering? Do you trade the ships yourself, or are they chartered out?

Interviewee #1	Interviewee #2	Interviewee #3	Interviewee #4	Interviewee #5
<p>“I've been doing all of that. The last ship I was working on was a ship that was owned by one person ship owner, who had an office to run the ship and that was on liner traffic. Very easy, very simple, very direct. I was also working for a company as shipper or charter where we chartered ships. The longest one was a seven-year charter. We did voyage charters. And then we did both liner traffic and spot markets.”</p> <p>“I mean for the charterer, the current landscape of liabilities. Doesn't really matter whether there's crew or not.”</p>	<p>“[the company] do everything by themselves. They don't need to worry about it, they are the kings. So if you go at the bareboat charter then you basically give the specs”</p> <p>“If I would be involved in a bareboat charter, I would be interested on the track record of the whoever I'm using.”</p>	<p>“We own our ships.”</p>	<p>"For us as a fleet, well, if you look at the [short sea] ships to start with, they are in essence chartered, you know the [corporate] owner and then we chartered them from them on a bare boat basis.”</p> <p>“I think that [another pair of sister ships are owned] and the mortgage is probably gone on those, but they also do chartering of lots of ships even on a time or bare boat basis on their other routes.”</p> <p>“We don't own that many ships now.”</p>	<p>"I know there's different ministries actually financing when we are talking about for example environmental. I know that that there is some like the Navy is chartering, but the ownership is a bit... Well, actually, let's put it this way. The financing comes from a different department than the Defence Forces, so there are cases, but that's not like typically the militant vessels would be. Of course, the ownership is quite clear, but still, it's the same government.”</p>

## 1.4 What is your business, and what is your business model? Who are your customers? What impact do onboard staff have on fleet operations?

Interviewee #1	Interviewee #2	Interviewee #3	Interviewee #4	Interviewee #5
<p>“you need to separate the business model from the business drivers.”</p> <p>“I don't know if the business model changes. Drivers might change and the liability questions might change pictures, but the business model will, most probably, as its barest form still be I need cargo space from point A to point B.”</p> <p>“Business model doesn't need to have current flow of cash might not change, the pressure is more on the current flow of liabilities.”</p> <p>“only 6% of the world ships cargoes is B2C stuff”</p>	<p>“the freight companies and the normal people that crossing with foot or by car.”</p> <p>“They had to really listen to the crew because you know. We have labour laws, and they are strictly followed. And if the company tried to break those, there were immediately the kind of basic questions that this is not OK we will go on strike or inform the Seaman’s union you learned this. It's not good. So of course, you need to be really careful with that, and of course, it all comes down to time. When you are on board, they want to use you as much as you would be able to work. So, there's limits.”</p>	<p>Sometimes chartered, primarily B2C or via travel agents. Driven by availability of itineraries relevant to homebase of customers.</p> <p>“Captain gets final say and no one would argue against that.”</p> <p>“Captain's got the yeah, the ultimate authority... we're having to train massively on accountability and leadership qualities for Captain, we're still. It doesn't matter.”</p>	<p>"The everyday is freight and then it's topped up with tourists. There's a small level of tourist all year round but obviously then you get the real major peaks around the holiday seasons.”</p> <p>"Contracts with hauliers which are in place which are reviewed I think biannually and then there will be those who just turn up and go. And of course, the rate for a turn up and go will be different compared to someone who's committed a certain volume to the business, but then also as well we've got an agreement with our competitor.”</p> <p>"The Masters’ [priority] now is fuel economy, closely followed by the schedule.”</p>	<p>"The integrity of territorial waters. I would say that's the main task.”</p> <p>"We would need to be collaborating with fleet wide at least so that the maintenance costs would remain as low as possible.”</p> <p>"personnel on the vessel ... are heard due to the fact that they are the ones doing the work.”</p> <p>"But maybe just to get some concrete like personnel wise, are you in a two watch system on board or are you in a three watch system the rotation wise, that that can be even with the ship's crew, so you don't need to get the approval from very high above ... at least I did that”</p>

### 1.5 How do you think MASS will impact your operations at the ship level/ fleet level/ shore operations? How do you see the impact on the total cost of ownership of a ship?

Interviewee #1	Interviewee #2	Interviewee #3	Interviewee #4	Interviewee #5
<p>“There's no way you can have autonomous regarding navigation without having an autopilot”.</p> <p>“In the big picture, it will take a lot of years before anyone even starts this looking at the calculation of not having the accommodation there. There will not be operational ships in the near future that have no accommodation at all”</p> <p>“Any changes in the organisation, any disruption in the day-to-day life is not worth 5% in OpEx savings. Whatever the cost is. So, saving salary costs has not been in one single discussion that I have been in when it comes to autonomy and automation around the world”</p>	<p>“the freight companies and the normal people that crossing with foot or by car.”</p> <p>“They had to really listen to the crew because you know. We have labour laws, and they are strictly followed. And if the company tried to break those, there were immediately the kind of basic questions that this is not OK we will go on strike or inform the Seaman’s union you learned this. It's not good. So of course, you need to be really careful with that, and of course, it all comes down to time. When you are on board, they want to use you as much as you would be able to work. So, there's limits.”</p>	<p>“we've got track pilot and speed pilot already which we can use. They're useful if they're set up the right way.”</p> <p>“Areas that don't talk to each other, so we don't, you know, we have to put it all together to get those pictures for the ships.”</p>	<p>"With these big box boats now, you know they're running around with what, 16 crew and the crew aren't there to maintain the ship. They're there just to operate it, and then it's built into, you know, the OpEx of the ship that it refits once every two 3-4 years and then all that works are done for them. So, I think that would probably stay the same."</p> <p>"It's whether the companies do it themselves, which they seem to at the moment or do they then lease it out and get someone else to monitor their ships for them, which is a pseudo ship management company in disguise."</p>	<p>"getting the situational awareness more and more on the close by and adding the Force Protection circle around it's apparent that the autonomous vessels it's a must."</p>

## 1.6 What problems will autonomy solve? Do you see further issues or potential unintended consequences?

Interviewee #1	Interviewee #2	Interviewee #3	Interviewee #4	Interviewee #5
<p>“The biggest flaw with that question is that we see when we talk about autonomy. How should I say that's a question that has a severe lack of imagination”</p> <p>“If you're looking at the topic in in the big picture, what problems are we solving? What are the drivers? Why do we want to have autonomy well? I think it's it's clear that that like in in some of the projects that that we're involved in, if you have a firefighting tug operating in the region that has an LNG terminal or an oil terminal, and you have a fire in an LNG terminal or a ship at that, LNG terminal you want to put that fire out. You don't want to put people close into that or in the middle of that for 12 hours. To have an autonomous ship or remotely</p>	<p>“Usually the autopilots or whatever they do it probably better than humans because we used to usually kind of oversteer or understeer. So we are touching the levers all the time, and that's basically not good. Usually, the computers, or some brain behind computers there, are making it most optimal. And humans, we tend to use too much power or too much angle... the ketchup bottle effect. You just give a little more command and maybe a little more, then it suddenly starts to come, and then you already have given too much command, and you have to counteract them.”</p> <p>“You know about Japan? And the age demographic there and how many vessels they have. And how many vessels</p>	<p>“you'd lose your crew, not your officer, because it's about the qualification of the officer being up on the bridge.”</p> <p>“[Liability will] still fall to the captain with quite a huge responsibility placed on the chief and obviously the company for installation overall, you've got your industry, your sort of corporate insurance at the corporate level as well. But because they would be in charge but for an operational thing, again it comes down to the master as the operational person.”</p>	<p>"Does a ship arrive at the pilot station, and then a pilot and a riding crew go on board to tie the ship up, and is it completely no one on board, or you know is there going to be a small operational team who are they are just there to maintenance if you like to keep the ship running? "</p> <p>"There are always unintended consequences, and you know the unintended consequence will be cargo ship aground, collision, and pollution. Because the system went wrong or the sensors went wrong, you know, malfunctioned."</p> <p>"As a merchant Navy, seafarers as a whole could die as a breed. "</p>	<p>"If we look at the Ukraine War, for example, what took place for their Black Sea flagship of Russian Navy, it got sunk... They used drones to saturate the radar and pretty much the SSM's came from 180 degrees from a different direction and they didn't even need to use multiple missiles due to the fact that they were concentrating on the drones."</p> <p>"The more we go to technology, the more it will require time to actually learn those items. So that's why staff members are quite elementary when we are talking about these naval vessels"</p> <p>"So you wouldn't be at the vessels anymore, but then this technology comes and</p>

<p>operated ship is a very natural way of thinking of that.”</p> <p>“...the domestic traffic of the coast of Japan, where they estimate that that they will not have crews enough to run their fleet by mid 24. So they will have to have people on board their ships, meaning that that that they are currently running a fleet of more than 3500 ships. And according to the Japanese constitution, the domestic traffic has to be operated under Japanese flag and the Japanese flag requires the Japanese language and Japanese passport for their cruise. The average age of those crews are 62 at the moment, so they will run out of people. Period. They have 417 islands that are dependent on these traffics, 417 islands with significant industrial activities, so, that's a clear driver. They don't want to get rid of people,</p>	<p>they need to get that country going. They are actually dependent on the vessels and if they don't have the guys to move those vessels, I think they don't, the only way they really can do it is to put autonomy there.”</p>			<p>you would need to start utilizing autonomous so capability. So there might be some pushback before getting the acceptance of the buy in is important in this case”</p> <p>”I see that fully autonomous from a naval perspective is that vessel or anything can do simple decisions by themselves, so they have a mission parameter, and with that they can do their own decision, even just on a simplest manner, it would be collision avoidance”</p>
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<p>they want to keep a system up and running. And they are seeing that that that from the average of 6 persons per ship, they have to see a way on how to go down to three. They don't want to go down to 0, but that they have to go down in watches. They can do a lot when the ships are in port. When it comes to maintenance and cargo handling, but the part that they are looking at that that is the most complicated to solve is the final approaches and on port manoeuvres. So everything else, port operations and the bit between approaches so open sea navigation they want to do as soon as possible with the help of technology. That's a driver." "one of the scenarios that that people are talking about if we go to the direction of the last discussions where the question is that about liability</p>				
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<p>and how do you define a ship owner when you don't have a representative on board and who's responsible of what? Then would we have a new kind of entity like if suddenly, as the discussion is now that that the technology provider should take a role as needed? Liability discussion because currently it is said that according to the basis of UNCLOS, the one who's making the profit from the asset is seen as the main liable party.”</p>				
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## 1.7 To what degree of autonomous or automatic technology would be a comfortable first step?

Interviewee #1	Interviewee #2	Interviewee #3	Interviewee #4	Interviewee #5
<p>“We will have to define subsystems. Products that that will support the idea of the ship as a system and then subsystems, and we will have to have a stepwise approach. We will have autopilot, we will have automatic crash tops, we will have electronic lookout function for detection and not connected to anything and so on and so on. And we will test and have regulations and legislation for each part of these on top of them. Seeing how they are going to be connected together into larger entities that that we call subsystems”</p>	<p>“The robots loading the robot. That's the optimal way.”</p> <p>“... these crane ships and metal ore ships, they sank quite easily because of shifting of the cargo. But the crew can't actually do anything for that. Suddenly that ship is missing, and crew is lost, so wouldn't that be good to put the autonomous vessel there? So, you would save those people, then who would perish because of the shifting of crane for bad weather?”</p>	<p>“But then there's kind of that, I mean obviously not the bridge officer, but there is that in place to go to drop down to single watch keeping and daylight hours or fridges. So you could.”</p> <p>Interesting errors related to automatic settings in auto pilot being input by human error</p> <p>“Which is great, but actually could you not go one step further and like just have something that shuts it all down automatically? Does your, you know, your fuel changeovers at the right time your... I mean, that's the that's that's the dream for cruise ship, isn't it? To be able to have a system in place, surely where the environmental stuff just takes care of itself?”</p>	<p>"Places that now offer remote pilotage. What will that look like? Will you end up with a conflict?"</p>	<p>"The use case would be for submarines that you would have those maintenance vessels, but they wouldn't be maintenance vessels. You would have like in some region, you would have five of those vessels and then somebody could just call them. These maintenance vessels will be unmanned and you would just call them for a certain location ... There's not that much navigation you need to do. You just need to make sure that the cargo stays intact, and that's about it."</p> <p>"Well, less crew. To improve the situational awareness without the abundance of crew members, so that's definitely a key. So if you can replace a look out or even 2 with the systems or have</p>

		<p>” But there's other areas on a cruise ship that could be looked at for autonomous control later on.”</p> <p>“Yeah, if it's still full to the captain with quite a huge responsibility placed on the chief and obviously the company for installation overall, you've got your industry, your sort of corporate insurance at the corporate level as well. But because they would be in charge but for an operational thing, again it comes down to the master as the operational person.”</p>		<p>better reaction times. So not just the view, but the better reaction times to counter any offensive that might come. So that's a very key item. ”</p> <p>"Well, I would love to have the drones to be honest, but maybe we'll stay on the surface only so. It will be the capability to improve the reaction times ... With a machine, you can have a 360 lookout all the time. And you can improve those certain capabilities, maybe in infrared or something else and you can have that close range. And maybe sleep your nights a bit more calmer."</p>
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