Università Ca'Foscari Venezia

Master's Degree

in Management

Final Thesis

Autonomous Shipping in The Emerging Scenario of Logistics and Transportation

Supervisor
Prof. Stefano Micelli

Co-Supervisor
Prof. Lucrezia Pari

Graduand
Ipek Gunay
Matriculation Number 881174

Academic Year
2021/2022

ACKNOWLEDGEMENTS

Living in countries surrounded by the seas, Turkey and Italy, means more than just an industry, I have always been curious about how one only industry can be so essential for a sector not only for economic aspects but also for perpetual autonomous development. This curiosity persuaded me to have an enthusiasm and even a dream to conduct my own research.

By using this chance, I want to thank my supervisor Professor Stefano Micelli and my Co-supervisor Professor Lucrezia Pari, who provided me with an opportunity to realize my dream and conduct my research on this topic and who has kindly guided me and gave me valuable indications from the beginning until the end of my research. Thank you, Dear Professors, I appreciate every effort that you have made to help me and the attention you have demonstrated throughout my research process.

I am also very grateful to my family, my dear (hayatımda gördüğüm en güçlü ve en merhametli kadın) mother Süheyla, (herkesin hayal ettiği ama sahip olamadığı baba) father Salih, (tosbik tosbik canım arkadaşım) sister Fuldan, (canım kardeşiiim) brother Alp, (Canım) Nazimim, my Italian family Mr. Mario, Uncle Loris, lovely Nonna Lyda, Alessandro, my (forever) friend Nebiyu, little sister Buse who have always been there to support me emotionally whenever I had doubts and difficulties. Thank you all for being in my life, not allowing me to give up when I am passing through tough times and always pushing me toward my dreams. Without you, I cannot imagine how difficult it would be for me to proceed with my thesis.

To my Family, always

being all the world with me

∞

Dünyanın her yerinde,

benimle olan birtanecik kıymetli aileme

Index

Introduction..*6*

Chapter I

Maritime Industry Current and Future Development...*8*

1.1 Introduction..8

1.2 The Development of Maritime Industry Under the Light of New Technologies 10

1.2.1 Industry Perspective..10

1.2.2 Vessel Perspective..14

1.2.3 Port Perspective 19

Chapter II

Autonomous Shipping as a Development Trend in Maritime Industry.........*22*

2.1 Unmanned Marine Vehicles (UMVs)...23

2.1.1 Unmanned Water Surface Vehicles (USVs) 23

2.1.2 Unmanned underwater vehicles (UUVs) 24

2.1.3 Remotely operated vehicles (ROVs) 25

2.2 Autonomous Ships..26

2.3. Standard Level of Autonomy 28

2.4 Major Companies in Autonomous Shipping Market and Their Current Activities 31

2.4.1 Kongsberg..31

2.4.2 Rolls-Royce 32

2.4.3 ASKO...34

2.5 The Place of Autonomous Vessels in the Existing Legal Framework.........35

2.6 Broad Approach to the Existing Legal Framework.......................................46

Chapter III

Case Study Analysis *48*

3.1 Research Methodology **49**

3.2 Analysis & Results of Data **56**

3.2.1 Implementation of AS and Their Strength and Weakness side **57**

3.2.2 Logistic Process Perspective & Technological Aspects **62**

3.2.3 Legislation Perspective **66**

3.3 Opportunities and Threats **67**

3.4 Potentially Future Market Scenario and Maritime Business Model **73**

3.4.1 Value Proposition **76**

3.4.2 Value Chain Architecture **79**

3.4.3 Revenue Generation **81**

REFERENCES ***87***

APPENDIX ***101***

Introduction

The concept of automation has been a major discussion point in the maritime industry over the last years. Its significance in the present and future scenarios of the international economy, as well as in the field of autonomous, cannot be overstated. However, the maritime industry, by always being well known for its efficiency in the global trade, has been prudent in the topic of adaption of new technologies because of possible disruptions in the transportation operations. Academic and sectoral debate occurred in response to the conclusions of recent scientific research on these subjects. At the same time, the fact of functioning in the age of the 4.0 industrial revolution required the industry to consider the advantages that new technology can provide. Impacted by industry 4.0, maritime 4.0 provided a variety of opportunities for the industry to build innovative solutions from real-time insights to remote operations to automated process optimization. The autonomous industry addresses the need to make sector more sustainable while also promoting inclusion and economic progress. Technological improvements in many industries are considered more than harbingers of the future. Since all of the many participants in technology are closely linked, their connectivity and collaboration with the efficient and successful management of the transportation system. Historically, the shipping sector has been largely reliant on a variety of ecosystems that include ports, vessels, vessel operators, owners of the vessel, owners of the goods, intermediary people and others. Within the maritime paradigm, a new innovation output known as autonomous vessels emerged. An autonomous vessel represents a turning point in the maritime industry, as Autonomous ships is uncrewed ships that carry containers, tankers, or bulk cargoes with less or no human interaction. Automation is gradually penetrating every part of the industry from autopilots and engine detectors to remote-controlled subsea and surface vessels that explore the seafloor. Shipping is an obvious focus area for automation; no doubt the gaps, defects, and opportunities to increase productivity in a periodically dynamic industrial sector make the issue much more interesting. The opportunity to achieve a competitive advantage through efficiency improvements is pressing the maritime market to reconsider its operating structure as maritime automation improves. Pollution, unemployment, competitiveness, cost structure, and market structure will be impacted not just by the local environment around the ship, but also by all parties involved in the ship's operational activities. While until a few years ago, autonomous vehicles were mainly used by the marine scientific research organizations and the defence industry for a wide variety of naval operations, nowadays, maritime operating entities that want to be a part of automation take advantage of current technologies to establish their own R&D and implement huge capacity autonomous cargo vessels. As the world moves towards automation, the consequences for the shipping industry are not yet known. Considering the enormous implications and potential automation for fleet operating processes and the maritime world as a whole, it makes the topic an important and relevant one to explore. The study aims at analysing opportunities and threats that autonomous vessels' bring and could bring to operating processes of global maritime businesses and the shipping industry, examining the digital transformation experienced on ships, investigate if autonomous vessels will be the solution to sea transportation under the light of their advantages and figuring out whether autonomous vessels are already falling under the same type of legal framework as traditional vessels. Moreover, by analysing the contributions and challenges to businesses and management activities coming with autonomous vessels, to support the thesis a further contribution to the identification of vessel automation will be given with witnesses and interviews of two autonomous maritime companies experiencing automation. The whole paper is structured 3 main sections:

Chapter 1: Focuses on the maritime industry current and future development by divided industry, ship and port perspective

Chapter 2: Define Autonomous shipping as a development trend in maritime industry

Chapter 3: Case Study with companies that are ongoing the most significant autonomous ship projects and supply technology supposition to the most prominent companies.

Chapter I

Maritime Industry Current and Future Development

1.1 Introduction

More than 90% of the import and export cargoes of the world trade are transported using the seas, and the capacity of worldwide trade carried out by the sea in the world is increasing day by day. Shipping by sea is the most cost-effective, efficient, and environmentally friendly option for most commodities. In recent years, maritime transport shows an improving trend in the total trade volume. The liberalization and growth in industrialization in national economies lead to a rise in demand for products while certain high-value, time-sensitive commodities are transported by air, this is an extremely expensive alternative.

Shipping is the global economy's lifeblood so, without ships, global trade, bulk cargo transit of raw materials, and the import/export of low-cost and produced commodities would be impossible. Seaborne trade continues to grow, helping customers all around the world through lower freight costs. The future development prospects of the business remain promising, owing to the rising efficiency of shipping as a mode of transportation and further economic liberalization. History reveals that maritime activities played an important role in establishing world domination of the state while contributing to the economy of the state when the time comes, at the same time, maritime activities provide the defence of the state. Human communities settled along the coastlines, over time, have created various types of ships, both starting from the materials they had and trying to cope with the concrete problems presented by the sea next to them. As a complex device, each ship type has revealed adaptable technological demands covering various economic sectors; it has also become a carrier of discoveries such as locations, routes, trade, and migrations. For these reasons, historians registered a trend according to which, the civilization levels of societies that were advanced in maritime have constantly increased faster than the others.

The seas have been a source of communication, a medium for the spread of culture and science, protecting trade routes has always been important since earliest times, so maritime power has been an essential and even an important actor of change, causing changes that have been determined turning points in the development of the historical process until today. Experienced processes have affected countries' perspectives on the maritime environment, their expectations from the sea, and their ability to evaluate what the sea offers to people and has formed the current structure of today's maritime sector.

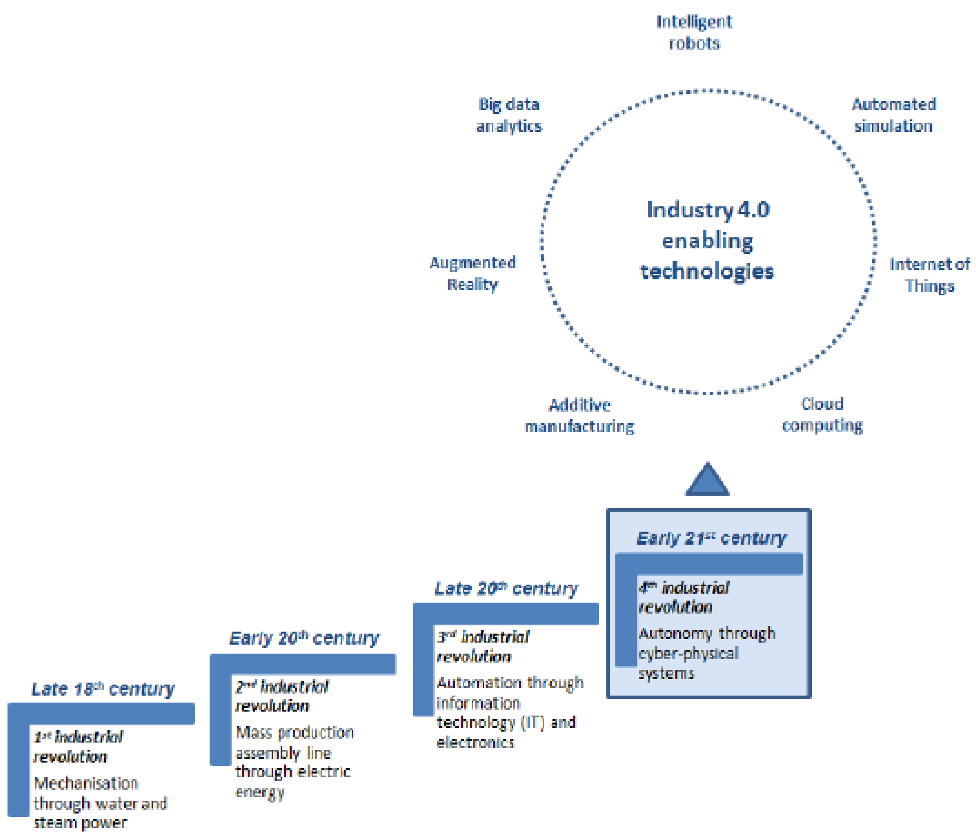
From a historical point of view, the common feature of almost all developed and wealthy countries is that they have fully embraced the maritime sector. The maritime strategy applied by developed countries; is remarkable because it understands the importance of the maritime sector and finds a scope of application in all areas of life, from the individual to the state (Çetin, Prof. Dr. Oktay, 2018). Human being has been in a quest for ages; they first discovered fire, then iron. The most important period of discoveries was the invention of steam technology and the industrial revolution. The use of steam systems in the first industrial revolution, the widespread use of oil in the second industrial revolution, and the invention of production line systems all improved production efficiency.

1.2 The Development of Maritime Industry Under the Light of New Technologies

1.2.1 Industry Perspective

With fast progress in the sectors of electronics, computers, and the internet, the third industrial revolution expressed itself as an informatics revolution. Industry 4.0 refers to the most recent industrial revolution in the digital age that described as the use of machine power to replace human power and can manage production processes itself (Ela Bulut, 2017). Figure 1 shows a high-level overview of industry 4.0, including a chronology of the four industrial revolutions' growth, as well as important features and fundamental technologies for industry 4.0 (Alfredo ALAN Flores., 2017).

Figure 1. Industry 4.0 progress timeline and technologies



Source: Article on Energy-Efficient Through-Life Smart Design, Manufacturing and Operation of Ships in an Industry 4.0 Environment

Industry 4.0 refers to a working style in which all processes are integrated by connecting the products and processes to a common network within the supply chain. The concept of Industry 4.0 emphasizes the place of information technologies in production and expresses that production is completely based on automation. With Industry 4.0, defining the business of production processes based on technology and devices that autonomously communicate with each other throughout the value chain. For optimal efficiency, vessels are complicated systems that generate and integrate volumes of data. To enjoy the full benefits of its, successful usage of sensors and internet of thing in industry necessitates a rethinking strategy.

Sea trading organizations have constantly used traditional transportation and connection means; for example, mass transporters, freight ships, radio signals, and that's only the surface of the iceberg. However, with the introduction of progressive innovation and concepts, it has been critical for trade organizations to gain new mechanical patterns for providing a lot faster and more effective trade administration. Smartness has joined the marine sector in recent years (for instance, smart containers, smart supply chains, and smart ports) as an implementation of intelligent digitalization. The digitalization of the sector could be the answer to several criticalities that affect the maritime supply chain, some of which are related to the lack of connection between the players involved. Indeed, it generally happens that the combination of weak connections between port infrastructures and limited or no transmission of data regarding delayed arrivals among carriers promotes the first-come, first-served and, as a result, a low level of predictability for maritime transport. Moreover, in parallel with the remarkable growth of traditional ocean-related movements, the sea takes seen a significant subjective and quantitative growth with the looks and progress of two new mechanical progress posts: the offshore oil discovery and creation industry, and the voyage area (Nikki Funke, 2014).

The huge increase of the overall population and the resulting expansion of energy demands in both developed and emerging countries require an increase in seaward hydrocarbon exploration and production. Another era of energy production was made possible by multiple achievements in the investigation, boring, stockpiling, and transportation techniques similar to the space industry, linking with numerous nations in penetrating projects off the coasts of seventy-four countries around the world.

On the other hand, gaining great relevance in the global economy, with an ever-increasing number of travels and sports boats departing from a large number and variety of ports worldwide, the cruise sector is more and more increasing, especially in specific areas of the world. The progression of technology is provoking several effects on the entire maritime sector. The development of mega-ships, robots that replace workers, new and updated materials, and elective energizers are just some of the innovations that are to cause a radical shift in the transportation industry. For this reason, it seems useful to briefly describe some of the digital solutions that are being implemented in both the maritime and port sector, to try to understand the basis of the innovation that will be analysed in the present thesis, concerning unmanned vessels. Most of the recent innovations in maritime sectors are linked to the increasing use of sensor technology and robotic automation. While these initiatives can improve and strengthen processes and manufacturing processes, comprehensive methods are essential for the industry to profit from data gathering. There are relevant factors in the development of the maritime industry, for example sensor technologies, cloud-based technology, solar and wind power for ships, although we will examine them in more detail in the following sections.

a) Sensor Technology

Sensor innovation is one of today's most impressive and well-developed innovations. With the arrival of sensors, there is no need to personally check the equipment on the boats. Connecting all of the equipment to sensors through remote availability allows the crew on the boat to keep exact control of the operating status of machines, the assistance required at periodic intervals, and their overall operability on boats. Additionally, if the sensors are combined with AI[1] and manmade brainpower, they may go to remote regions and analyse the data, instantly, sending warnings if any of the boat's sections require maintenance. The technology used to monitor ship operations and performance is constantly increasing. Future ships will feature a comprehensive network of sensors to monitor all aspects of functioning, including detecting problems and identifying places in need of maintenance or repair. In addition, more robust ship-to-shore communications will allow a land-based team of fleet managers to handle the majority of the ship's

---

[1] Artificial Intelligence uses computers and technology to mimic the human mind's problem-solving and decision-making skills.

operations. Linked with sensor technology, the Internet of Things is mainly made up of a GPS and a cloud-based data collection that saves all of the information gathered by the boat's electronics. As anticipated in the previous paragraph, IoT also connects sensors, robotics, and other tools via a distant organization. The advantage of implementing IoT is that the transportation service will be able to provide better customer service and provide clients with information on the place, the season of appearance, and shipping delay.

b) Cloud-Based Technology

Cloud-based innovation is recognized for successfully giving access to information and, as a result, will end up being a game-changing innovation for the transportation industry. Cloud-based innovation is just another resource for the transportation industry, from lowering costs to preventing information accidents, providing remote access to corporate information, and strengthening the correspondence channel between personnel abroad and lands.

c) Solar and Wind Power for Ships

The shipping industry is investigating renewable energy to power future fleets. Some of this technology is already in use and being tested. The Turanor PlanetSolar is a solar-powered catamaran that has successfully turned the world. However, the most likely commercial use for this technology will be systems that cut fuel usage by supplementing the existing power source with on-board wind turbines or solar panels (Leo McLeman, 2021).

1.2.2 Vessel Perspective

Realizing that intelligent ship navigation has substantially improved due to digitalization initiatives, there is increasing consumer demand for ships to be more advanced and efficient. Provisions for collision avoidance, information flows, monitoring, alerts, satellite communications, combined ship management, and assistance of port manoeuvring are among the requirements. Digitization and the changing dynamics of the shipping sector require a rethinking of how linked systems and internet of things might utilized to accelerate the following step of vessel development. There is a need for increased efficiency in design, construction, and operation, allowing firms to design vessels that best match the needs of their customers and markets (Brendan P. Sullivan, 2020).

Many businesses, particularly from Scandinavia and Japan, are developing full-size autonomous ships to be able to carry cargo or even passengers. The most advanced development appears to be being done by Kongsberg and Rolls-Royce. They just won financing from the European Commission "the 'Auto ship' project" for 20 million euros, which is part of a total project cost of 27.6 million euros. Two autonomous ships with remote control and the essential equipment will be created within two and a half years under this concept (Commission, 2019). Today, marine digitalization is primarily concerned with rate and volume optimization, as well as operations and navigation implementation evaluation (Brendan P. Sullivan, 2021). These priorities have an impact on value outside of the vessel, such as improved customer relationships and more effective decision, more efficient transportation systems, new operational strategies, with applications in the key segments: new applied innovative transportation, remote control systems, maintenance, live tracking, advance route planning, risk management, ship monitoring, mariner management and their training (Brendan P. Sullivan, 2021). The possibility of several autonomous systems towards assistance ports, part of the ship management flows, and awareness of the situation has been investigated (Brendan P. Sullivan, 2021). The system may function in a predictive and self-managed form to address issues in real-time by integrating diverse data. Those ships try to improve the maritime sector's safety, durability, and profitability by combining technology so can say that it is a radical change from traditional manned vessels.

With the change on technology side also it's effected the design and construction of vessels (Brendan P. Sullivan, 2021). Historically, the industry's capability to apply historical data has authorized it toward develop continuously while remaining highly competitive. Nonetheless, shifting customer needs and growing demand for futureproofing has produced an atmosphere that forces engineers, shipbuilders, and operators to create ever more increasingly complex vessels (Brendan P. Sullivan, 2021). The maritime sector is continually changing due to economic, political, social, and technical developments, from ship design and maintenance to cargo route optimization. As a result, the usage of digital technology has been recognized as a potential ar ea for development that might help in the proactive and responsible resolution of these difficulties. Despite acknowledging the value and significance of digital technology, there is still a substantial difference in how these technologies will be incorporated and eventually support next-generation ship development (Brendan P. Sullivan, 2021). Ship technology, construction, and material advancements will result in ever larger mega-ships, especially in the container shipping industry. Manufacturers will aim to capitalize on the decreased shipping costs that these vessels may give by designing their products to make the best use of this container capacity. Maritime vessels are technically challenging systems impacted by a range of aspects and developed in an iterative and multidimensional process (Christina Vossen, 2013). Identifying the fundamental design type is an important step in determining the characteristics and methods that will be followed from concept to delivery. Designers are provided to develop cost-effective systems that can accomplish specified duties while following both international and national rules and regulations, guided by stakeholder demands and resulting requirements (Molland, 2008). Within the range of technologies that as mentioned on top are being implementing by designers and engineers, the following are the widest spreading:

a) Internet of Things Technology: Review of the vessel design method, downstream processes, integration of data from sensors and personal user information into the design process is limited, although it is a developing field of research (Brendan P. Sullivan, 2021) (Trivyza, 2016) (Pakkanen, 2016). Whereas the application of these kinds of data has been limited so far in this, there are numerous instances of vessels in production that use significant improvements to increase fuel efficiency, maintenance, design (Brendan P. Sullivan, 2021) (Pakkanen, 2016).

b) Intelligent simulation: with this directly input data from vessels during moment operating situations allows for the creation of computer based aided design and engineering solutions. Vessels may start testing and optimizing the design with improved sensors and IoT devices, substantially cutting construction period, that well known which materials and building process (Brendan P. Sullivan, 2021) (Ang, 2016).

c) Virtual Reality: relates to a realistic screens and other platforms are used in an interactive system (Brendan P. Sullivan, 2021) (Gandolfi, 2018). Progressing of virtual reality technologies is decreasing the cost of adoption, and the facility to show complex scenarios in a virtual atmosphere allows customers, operators, to interact with the design in unprecedented detail, providing greater insights into the ship's functions or layout (Brendan P. Sullivan, 2021).

With specific reference to autonomous vessel’s construction and using, below are the some of the most innovative tools:

d) Intelligent Robots: Robotics and automated manufacturing are attractive fields that have the potential to increase ship quality and dependability. In recent years, robots in all fields have become quite common. Robots are increasingly being used to assist all projects in the delivery industry. Robots can effortlessly complete tasks such as pressing, delivering, analysing, and fighting fires. As robots perform more effectively and without interruption, the delivery industry is expected to become increasingly dependent on the use of robots in all capacities. New types of robots, known as ‘smaller than expected robots,' are being combined with sensors to differentiate and record all information in the boat and work on it (Oneto, 2016) (Raptodimos, 2016) (Gandolfi, 2018).

Robots are used in the marine sector for a variety of cleaning and maintenance to totally unmanned ships. The SEA-KIT of Maxlimer is an excellent example of a completely robotic ship (Marine Digital, 2021).

Figure 2. Sea-Kit of Maxlimer

Source: sea-kit.com

When we look at today, we see that robots are generally used in the cleaning and maintenance of ship hulls. The overgrowth of the body has a significant impact on fuel consumption and, as a result, hazardous emissions. Cleaning the hull on time might save up to 12% on fuel expenditures. Thus, to protect the operational capability of ships, regular cleaning may be carried out without putting humans at risk (Marine Digital, 2021). As an example, from fire robot on ships, the SAFFiR can detect and extinguish fires on the vessels and work with firefighters seaman. These robots can conduct activities like controlling valves, collecting, moving fire hoses, looking for survivors in the case of a ship fire, and tolerating temperatures of up to 500 degrees Celsius (Marine Digital, 2021). Also, anti-piracy Robots, “Recon Robotics” are small robots that can access a vessel's main deck for stealth inspections with some sensors and tiny cameras to examine the problem.

e) Additive Manufacturing: The building of nautical vessels is definitely a costly and time-consuming operation that involves several people, procedures, and materials. It looks to be well suited for the maritime sector and will most likely provide significant savings in shipbuilding and maintenance (Housel, 2015) (Kostidi, 2017). Because of the new technologies and materials, development costs continue to drop, which benefits shipyards trying to improve their production capacities. This one will be demonstrated by additive manufacturing's capacity to replace existing manufacturing methods by eliminating non-value-added phases of production. This encourages acceptance, affordability, and the creation of elements with intelligent features, such as integrated sensors.

f) Augmented Reality: It contributes to construction sites by allowing people to engage with virtual in a physical environment. This system solutions support in the completion of daily work by giving additional information that enhances employees' capacity to engage with and identify problems in a physical environment as will see in autonomous ships.

1.2.3 Port Perspective

The growing size and cargo volume of commercial ships require that ports become more digital, sustainable, and linked. These requirements show the complexities of today's port infrastructure and identify the peculiarities of a very competitive environment. Because of the competition between the various stakeholders involved in the maritime and port industry, a renewed need to speed up the sector's digitalisation process has arisen.

Indeed, by allowing the connection between the many players of the ecosystem, the implementation of innovative systems for data sharing will increase the coordination level of both port operations and supply chain management. Historically, what happens at sea has been regarded as a distinct practice from the one happening in ports but nowadays, however, it has become clear the need for effective connection between ports and ships and the consequent need for the introduction of informatics systems aimed at improving ship-to-shore data sharing. When we look at the port logistics side, every port is differentiated by a sophisticated structure of people, goods, and modes of transportation that produce and use large volumes of data. In this perspective, the 5G connection will become more important for any future technological application with a thousand times larger data traffic capacity than 4G and exceptionally low latency periods. Furthermore, 5G integrated with the Internet of Things allows trucks, ships, cranes, and even containers to be connected into a single network and share digital information. Improvements in working methods at the harbour, with the help of innovation, can reduce the number of times vessels must stand by at the port. The reduced holding period will result in fewer fossil fuel waste from ships in ports. To speed the dumping of the boat, it is necessary to use robots and other hardware to handling heavy cargoes.

Port automation is supported technology to provide intelligent solutions for the effective control of traffic and trade operations on the port, accordingly, improving port capacity and efficiency. Smart ports (or automated ports) typically use cloud-based technologies to aid in the creation of operational processes that allow the port to operate efficiently. Currently, most ports across the world have some level of technology incorporated, if not full management. Furthermore, the number of smart ports has gradually increased as a result of worldwide government initiatives and the exponential rise of maritime trade.

The port of Hamburg, Germany, is an example of a smart port that combines cloud-based technologies to manage energy resources, traffic management, infra structure, and port property for effective port operations. The progress of port automation may be viewed in a variety of ways. These include material unloading and cargo handling equipment, ship record digitalization, inventory management, infrastructure development, ship docking and maintenance assistance, and more. The gates, Ship-to-Shore cranes, and stacks are the three main areas of port automation in general.

a) Automation at port gates

The port gates act as an important step for recognizing and registering all entities entering and exiting the port. Extra safety procedures, identification, customs, immigration, and quarantine are all included for ships. These are critical operations that must be completed to secure the port's safety and need the deployment of strong security measures. Due to manual limitations, these operations take a lot longer time as the amount of container transit through the port increases. Basic operations like entry/exit logs, identification, and docking payments may all be automated with the right technology. This makes the entire process operate much more quickly and efficiently (SHM, 2018).

b) Ship-to-shore cranes

During the ship-to-shore delivery of goods carried by ships, logistics management with IoT plays a role. Cranes, both manned and unmanned, are frequently used for unloading. When it comes to container transportation, just 30 ports all through the world can be considered fully automated. Unmanned horizontal transportation or unmanned yard cranes are used to deliver containers from ships to the terminal using automated cranes. These are categorized according to the kind of cargo and put in the inventory accordingly. These container handling technologies are consistent, probable, and efficient. Since the cranes are managed by a computer, the planning and implementation processes become highly efficient, resulting in the best possible results in the shortest amount of time (SHM, 2018).

c) Stacks and Inventory

It's time for the robots to take over after the cargo has been unloaded at the port. Containers are stacked according to the category given using cargo handlers and stacking cranes. The inventory is frequently organized by the date of inland departure. When the container is ready to be dispatched for further transportation, robots are utilized to transfer it to the appropriate station and prepare it for the route ahead. Designing robotic equipment to help in transporting goods, one of the most significant factors is safety. The intelligent design considers the level of human-machine interaction. In addition, the entire process is reviewed to verify that inventory flow is optimized, and that no friction exists in multiple operations (SHM, 2018).

There are some advantages and disadvantages to port automation. When we talked about the pros of port automation; better control over port emissions, saving of time and resources, improved stability because Sensors and other digital equipment used in port operations planning ensure that procedures are extremely stable. Automated processes are tidier than traditional process flows since speed and safety are both prioritized, and long-term benefits in automated systems do not require constant monitoring after they have been set up. The port is free of manual interference and can control board for many years. Within cons of port automation are high capital investment costs, the reaction from labour unions, cyber security risks and high maintenance costs.

CHAPTER 2

Autonomous Shipping as a Development Trend in Maritime Industry

“An Unmanned Vehicle (UVs) is defined as an electro-mechanical system with no human operator aboard, that is able to exert its power to perform scheduled activities” (National Institute of Standards and Technology Special Publication, 2020). “UVs can be controlled remotely, by a remote pilot, or can navigate autonomously based on pre-programmed plans or more advanced dynamic automation systems” (Anon., 2014). They include vehicles moving:

- in the air, Unmanned Aerial Vehicle or System—UAV, UAS, commonly referred to as "drone",
- on the ground; Unmanned Ground Vehicle—UGV,
- at the sea surface; Unmanned Surface Vehicles—USV,
- in the water column; Unmanned Underwater Vehicles—UUV

Today's unmanned vehicle (UV) systems are tele operated, semi-autonomous, or rely on extremely fragile autonomous capabilities. As a result, mission accomplishment requires the human being a closely linked system component. Human operators face challenges such as the need for several personnel to assist a single UV operation and intellectually demanding activities associated with UV missions. Individuals or groups of fully autonomous UVs will be deployed in future UV systems. Humans will most likely play roles like as supervisors, operators, mechanics, peers, or spectators in these UV systems. These UV systems will need the UV's ability to see the environment accurately, understand the situation, identify, and interact with environmental factors, and communicate mission objectives to team members or superiors.

UMVs are operate with some control or no involvement from an operator (Roberts G., 2006). UMVs are primarily used in oceanographic research and include sensors for a variety of purposes including navigation, guiding, and data collecting (Blanke, 2000). Most UMVs are controlled by rechargeable batteries, although certain vehicles powered by semi-fuel cells made of aluminium (Guibert, 2005). UUV, ROV[2], and USV are all included in the definition of unmanned marine vehicle (UMV). The next section provides an overview of the UMV types and their uses.

2.1 Unmanned Marine Vehicles (UMVs)

2.1.1 Unmanned Water Surface Vehicles (USVs)

USV, which operates on the water's surface without a crew and may be teleoperated or navigated autonomously. USVs are commonly used for port and infrastructure security, coastal patrols, search and rescue activities, and the short distance logistics (Jorge, 2019).

Figure 3. Examples Unmanned Surface Vehicle

Source: (Autonomous Boats & Unmanned Surface Vessels for Marine Monitoring, 2021)

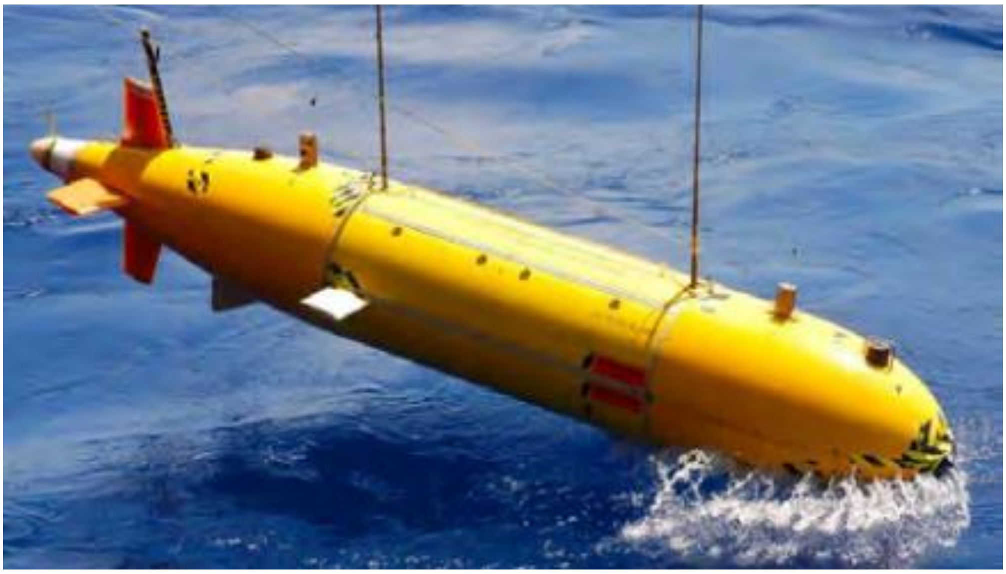
[2] *Remotely Operated Vehicles*

USVs may operate in hazardous and unsafe situations to ensure human safety because this type of vehicle low operating expenses. USV also uses for ocean surveying, seafloor mapping, and inspection of structures up and down of water (Narayanan, et al., 2019). USVs should have appropriate environmental awareness to identify and avoid obstacles up and down the water, to assess their movement and distances, and to identify the boundary between water and land in coastal areas.

2.1.2 Unmanned underwater vehicles (UUVs)

Recent progress in the technology movement, energy, and propulsion systems are being used to build technology that allow for significantly more efficient involvement, monitoring, and investigation in the seas. As a result of these developments in ocean technology, the autonomous robotic platform is gaining popularity.

Figure 4 . An example of UUV



Source: (Somaiyeh MahmoudZadeh, 2018)

In the seas, UUVs are used in a variety of applications, and some of these applications, particularly in critical tasks, need precise vehicle control. Previously, UUVs could only do a limited tasks but with the improvement of high energy supplies and advanced processors, nowadays' UUVs can accomplish increasingly complicated tasks and missions. Their sizes range from portable to greater diameters, with each class of vehicles having its own set of advantages and applications.

UUVs are utilized for a variety of operations with varying responsibilities and purposes. Oil and gas companies frequently utilize UUVs to create a map of the seafloor before building subsea infrastructure, allowing pipelines and subsea completions to be constructed in the cost-effective and environmentally friendly possible (Akçakaya, 2009). UUVs are being used for also underwater scientific investigation, coastal area monitoring, turbulence measurement, and offshore mining (Iwakami H., 2021). Prior to submitting subsea infrastructure, the oil sector uses UUVs to survey the seafloor in detail. UUVs missions are presently being carried out in order to improve knowledge different sectors such as climatology, marine ecology, and ocean bed geology. This sort of vehicle may also be used to study seismic activity, seabed geotechnics, and ocean circulation.

2.1.3 Remotely operated vehicles (ROVs)

The term refers to connected underwater robots used in the offshore industry. ROVs, as compared to UUVs, are teleoperated robots that are highly manoeuvrable and controlled from a command centre. They are connected to the control station via a link, which is a cable that transmits electrical energy, audio-visual, and data signals between the controller and the vehicle. Usually, they are fitted with a camera and lights to increase the vehicle's capabilities, additional equipment is frequently added.

ROVs, like UUVs, may be utilized in a large range of difficult missions. ROVs are widely applied for undersea salvage, inspections, installations, and maintenance operations, but they may also be operated for educational objectives like mine-clearing, ecological inspections, iceberg searching, oceanographic research, and submarine photography (Petersen, 2009). ROVs can operated for emergency scenarios that assistance tasks are required such as environmental crisis caused by the Gulf of Mexico oil spill in 2010.

2.2 Autonomous Ships

- Autonomous ships are best viewed as the next step in the evolution of a ship's current subsystems, which collectively form an autonomous vessel (M. Schiaretti., 2017).
- Autonomous ships will be the result of improving traditional ships with several supporting innovations, but the new means of integrating ships to various processes creates a strong case for smart shipping being a disruptive business model innovation (Martimo, 2017).
- Autonomous vessels are the ships that controlled from a shore control centre, where masters and engineers monitoring and control navigation with using detectors, sensors, high-resolution cameras, and powerful satellite communication systems.

Conception of autonomous vessels was at first mentioned in the 1970s in Rolf Schonknecht's book "Ships and Shipping of Tomorrow," which said that in the future, Captains would perform their responsibilities from an onshore office building and the ships would be navigated using computers. During the 1980s, the Japanese investigated deeply into this idea in an effort to reduce the high crew costs, but the adoption of a cheaper foreign crew with the usage of flags of convenience ended their promising research project. Later, in the 1990s, a ship designer stated that using GPS, ships might sail short distances unmannedly, whereas a naval architect mentioned that artificial intelligence could potentially be used to ships. Considering the research conducted over the last two decades, the concept has remained unattractive to shipowners, due to the large investment and maintenance expenses required. The huge step occurred in 2007, when Waterborne TP, a team of maritime stakeholders, in a document explicitly specified how an autonomous ship would look like, and they indicated that further automation would be beneficial to the maritime community (Opensea.PRO, 2021). The Korea Research Institute, financed to led the development of autonomous ships for maritime survey and surveillance in 2011 (Roberts, 2019). The European Commission supported Maritime Unmanned Navigation with Intelligence in Networks (MUNIN) under the Seventh Framework Program in 2012. This project's goal to explore technological, economic, and legal potential of autonomous vessels. Their goals were to create and test an autonomous ship, that would be described as a vessel and controlled by automated on-board decision systems, however, is managed by a remote operator at a shoreside command centre (MUNIN, 2021).

When we look at the major components of autonomous ships mainly, autonomous ships are made up of four major components (see Table 1):

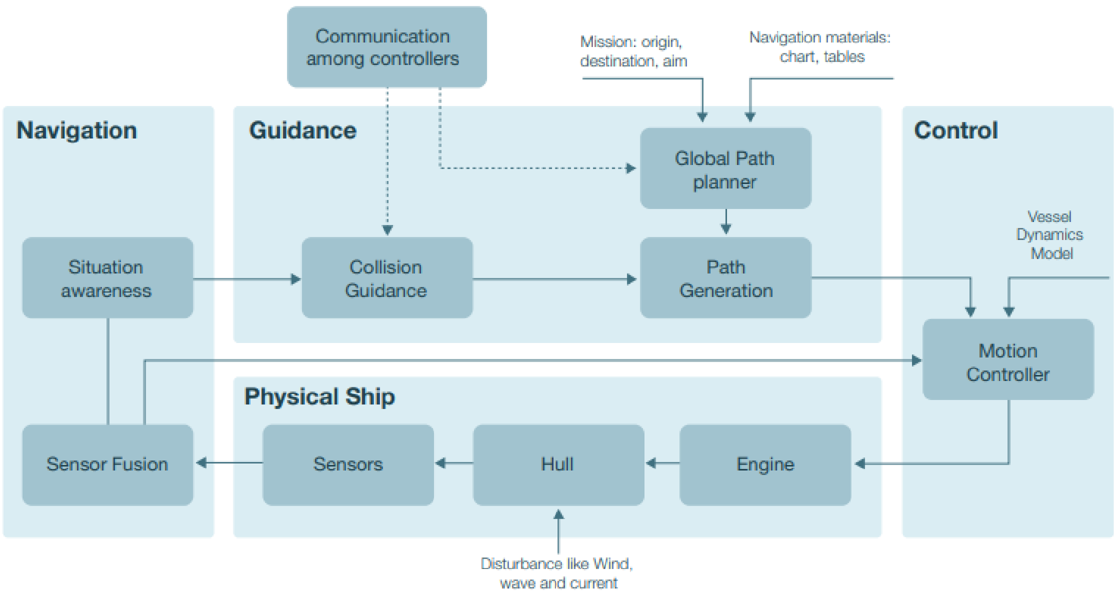
a) Navigation: An autonomous ship's navigation systems collect data from numerous sensors on the ship. A software-based sensor fusion block match data since these sensors to build a picture of the actual world. Situation awareness, a software-based system, evaluates these pictures in order to convert the data into actionable information.

b) Guidance: The navigation subsystem uses the image provided and evaluated via guidance subsystem to plan the ship's direction. Various factors must take into account like collision avoidance, the path origin to destination and other navigational factors, and the condition of many other ships. The ship's route is generated by combining these several information components.

c) Physical ship: Additional technology on the physical vessel is required to collect data to assist the software-based decision-making system.

d) Control: The control system, commonly known as the signal controller, is responsible for the correct direction.

Table 1 . Parts of an autonomous ship



Source: smartport.nl

2.3. Standard Level of Autonomy

One of the identifying elements of an autonomous ship that its capability to perform autonomously. Autonomy is classified into six levels (see in table 3), degree 0, with human interaction, to level 6, full autonomy. This levels may be split into four stages:

1. The traditional method of operation
2. Increased sensors and decision support
3. Autonomy aided by humans
4. Full autonomy

Autonomous ships and their operational systems are highly automated or remotely controlled ships. These ships use technology to automate some, or all of the onboard duties connected with ship operations, such as detecting its surroundings, monitoring equipment status, ship manoeuvring, engine control, cargo management, loading, docking, and undocking, and so on.

In the first phase, which serves as a proof-of-concept phase for autonomous ships, issues related to autonomous ships are identified, suitable technologies are developed, and the effects of the promotion are analysed. In some situations, such as for use onshore ships and in restricted sea regions, it may be feasible to go to the practical usage stage. IoT ships will be introduced in the second phase, which will gather and analyse sensor data and given decision option like route guidance and engine or in the engine room failure alerts.

Ships with automated functionalities will be implemented in the third phase. These ships will connect with one another, integrate onboard equipment, and utilize advanced data analysis and artificial intelligence technology to provide a specific action plan for the crew to execute. Ships having onboard technology that can be controlled from the shore, as well as systems for providing information in an audio-visual mode for sailors' decision-making, are also emerging at this level. However, it is concluded that the final decision-makers will continue to be sailors at this point.

Ships with improved automation tools will be implemented in the fourth phase. These ships will be provided with equipment that will function effectively during berthing and berthing operations, as well as in a variety of maritime traffic and weather circumstances. These ships are expected to have a significant degree of autonomy, and there will be moments when the final decision maker is not a captain.

Commercial ships are provided with electronic navigation equipment that provides information on the ship's position like GPS, distance to other ships, their direction and speed, and expected trajectory, as well as electronic charts. A manned navigation bridge and, in some cases, a person to monitor surrounding seas are essential for ships. Large ships are navigated by drawing a path on an electronic chart. The ship is kept on track by an autopilot. For navigating or handling error situations, manual control of the propeller and main engine is required.

At the 103rd meeting of the IMO's Maritime Safety Committee (MSC) in May 2021, four degrees of automation were given as definitions of autonomous ships (IMO, 2021).

Table 2. Autonomy levels of maritime autonomous surface ship (MASS)

DEGREE 1	Ships with automated processes and decision support	Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised but with seafarers on board ready to take control.
DEGREE 2	Remotely controlled ship with seafarers on board	The ship is controlled and operated from another location. Seafarers are available onboard to take control and operate the shipboard systems and functions.
DEGREE 3	Remotely controlled ship without seafarers on board	The ship is controlled and operated from another location. There are no seafarers on board.
DEGREE 4	Fully autonomous ship	The operating system of the ship can make decisions and determine actions by itself.

Source: IMO Press briefing, "Outcome of Regulatory Scoping Exercise for the Use of Maritime Autonomous Surface Ships (MASS)"

Furthermore, Lloyd's Register of Shipping has recommended more precise terms than the IMO by proposing a framework for grading the autonomous level from Level 0 to Level 6, considering the degree of each advanced function, the placement of the assisting function, and the degree of human participation.

Table 3. Autonomy levels by Lloyd's Register of Shipping

	AUTONOMY LEVEL (AL)	**DESCRIPTION**
AL 0	Manual - No autonomous function	No autonomous function. All action and decision-making performed manually
AL 1	On-ship decision support	All actions are taken by a human operator, but a decision support tool can present options or otherwise influence the actions chosen. Data is provided by systems onboard
AL 2	On and off-ship decision support	All actions are taken by the human operator, but the decision support tool can present options or otherwise influence the actions chosen. Data may be provided by systems on or off-board
AL 3	"Active" human in the loop	Decisions and actions are performed with human supervision. Data may be provided by systems on or off-board
AL 4	Human on the loop – operator/supervisory	Decisions and actions are performed autonomously with human supervision. High impact decisions are implemented in a way to allow human operators to intercede and over-ride
AL 5	Fully autonomous (rarely supervised)	Rarely supervised operation where decisions are entirely made and actioned by the system
AL 6	Fully autonomous (with no supervision)	Unsupervised operation where decisions are entirely made and actioned by the system during the mission

Source: Lloyd’s Register seven levels of autonomy (Maxwell, 2018)

2.4 Major Companies in Autonomous Shipping Market and Their Current Activities

In this section, we will examine big and emerging autonomous ship companies. As there will be interviews and analysis with the largest companies, Yara International, DNV, Mitsui O.S.K Lines, Massterly in the last section of thesis, detailed explanations of these companies will be included in the case study part. For this reason, companies that are running or supporting other autonomous ship projects will be described in this section.

2.4.1 Kongsberg

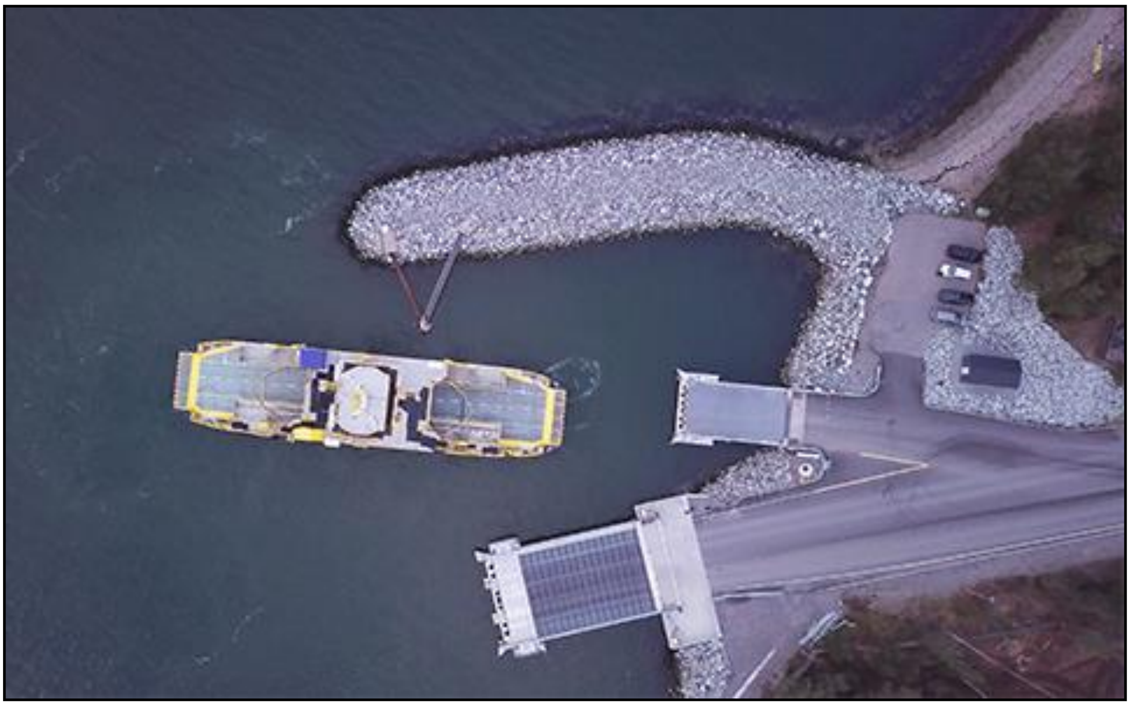
Kongsberg is part of the industry in developing autonomous ships and systems of autonomous ships. It not only plays a role in autonomous ships, but also contributes to complementary technologies, such as sensor technologies and projects' collision avoidance. At the same time, as Kongsberg is one of the ship simulation manufacturers, it also carries out the testing process of automation ships and completed projects along with the projects. Both projects were highly productive, but it was really difficult to integrate them. Kongsberg has been involved in many projects and has cooperated with leading manufacturers in the industry. Some of them mentioned on below:

- Yara Birkeland is the world's first all-electric and autonomous container ship with zero emissions and Kongsberg is responsible for all key enabling technologies for this project, in addition to electric propulsion, battery and propulsion control systems, including sensors and the necessary integration for remote and autonomous operations.
- Wilhelmsen and Kongsberg have joined forces to take autonomous shipping to the next level by providing a whole value chain for future autonomous ships, from design and development through control systems, logistical services, and ship operations, resulting in a company that truly matters for autonomous ships; Massterly.
- In collaboration with Kongsberg and the ferry company Bastø Fosen, a system has been developed in Norway to automate the passage between Horten and Moss and move ferries from the coast.

2.4.2 Rolls-Royce

Rolls-Royce has strong history in aviation as manufacturer of aeroplane engines. The company in the autonomous vessel industry aims to be exclusively a system supplier. Rolls-Royce does not intend to create own ships or even all of the necessary technologies. They supplying a technology that will allow remote control of the ships. They will test and improve the various components of their system in real time. As planned in early 2018, Rolls-Royce and Finnish state ferry operator Finferries teamed up for autonomous systems. Providing service in Finferries in Turku city of Finland since 1993, "Falco" was reflected in the press in December 2018 as the world's first fully autonomous car ferry. It is stated that the ship detects objects and avoids collisions by using sensor fusion and artificial intelligence, the newly developed autonomous navigation system provides automatic docking, and the return journey is remotely controlled. It is stated that the automatic docking system was among the technologies tested during the said test, and this feature is a system that allows the ship to automatically change its course and speed as it approaches the pier, and to dock automatically without human intervention. (Rolls-Royce, 2018) (Insight, 2018)

Figure 5. Autonomous ferry "Falco" tested by Rolls-Royce & Finferries



Source: Rolls-Royce,2021

Experience of the world's first fully autonomous and remotely controlled ferry journey has begun on the Falco ferry, and the development of the project continues with Kongsberg acquiring Rolls-Royce Marine (FinFerries, 2020). As the last update in Copenhagen harbour, Denmark, Rolls-Royce, and international towage operator Svitzer successfully demonstrated the world's first remotely piloted commercial vessel. One of Svitzer's tugs, Svitzer Hermod, successfully completed a series of remotely controlled moves earlier 2021 (Rolls-Royce, 2021).

Figure 6 . Rolls-Royce and Svitzer Hermod's remote control tug control center

Source: Rolls-Royce website

2.4.3 ASKO

ASKO can be thought of as a joint project of Kongsberg and Massterly, rather than as a separate company in the autonomous shipping market. The company currently transports its cargo in more than eight hundred trucks a day and is dedicated to sustainability and has made significant investments in innovative technologies such as electric and hydrogen-powered vehicles because of that, has ordered two autonomous ships to be delivered at the beginning of 2022 to navigate between Moss and Horten ports in Oslo fjord. These ships are equipped with the necessary technology by Kongsberg Maritime for zero emissions and unmanned operation and will be managed by the Massterly company from the remote operations center in Horten Port. Both ships are planned to initially operate with a reduced crew prior to totally autonomous (Massterly, 2020) (Executive, 2021).

Figure 7 . ASKO Autonomous Ship Concept

Source: Wilhelmsen.com, 2020

2.5 The Place of Autonomous Vessels in the Existing Legal Framework

In the beginning, is an autonomous vessel, still accepted to be a vessel as there is no master or crew on board? If not, the question of whether those vessels are regulated by maritime law. Does maritime law apply to all crafts operated in the water?

The person in command of the ship, is assumed to have the full control and direction over it. However, what if there is no person onboard, and the person responsible for the ship, or even simply monitoring its operations, is on shore in an office?

IMO has begun research on how MASS operations might be handled by IMO instruments in a safe, secure, and environmentally way. For the objectives of the regulation scope research, a "MASS is described as a vessel that can function independently of human contact to varied degree (IMO, 2018)."

The term is not clearly defined under maritime law (Tetley, 2002). Even the United Nations Convention on the Law of the Sea, which accepts the English terms ship and vessel interchangeably, does not define it (S Rosenne., 1982). The principles of the Law of the Sea, define nations' rights and obligations into international shipping, therefore relate to the operation of autonomous vessels.

The majority of international public law maritime conventions apply terms that are specific to the situation. The term "*ship*" is defined as "*any self-propelled sea-going vessel used in international seaborne trade for the transport of goods, passengers, or both, with the exception of vessels of less than 500 gross registered tonnage"* under the United Nations convention on Conditions for Registration of Ships (Hooydonk, 2014).

Many conventions concerned with private maritime law apply to ships however do not define them. 1910 Collision Convention[3], 1910 Salvage Convention[4], and 1999 Ship Arrest Convention[5] are examples of these conventions. There are legal instruments containing definition of "vessels", although even these have a large range of options or a very broad definition;

---

[3] *Convention for the Unification of Certain Rules of Law with respect to Collisions between Vessels*
[4] *Convention for the Unification of Certain Rules of Law respecting Assistance and Salvage at Sea*
[5] *International Convention on the Arrest of Ships*

- Vessels are defined by the Hague Rules[6] as "*any vessel used for the carriage of goods by sea*"
- In 1992 International Convention on Civil Liability for Oil Pollution Damage as "*any sea-going vessel and seaborne craft of any type whatsoever constructed or adapted for the carriage of oil in bulk as cargo*"
- In 1989 Salvage Convention[7] as "*any ship or craft, or any structure capable of navigation*"

The definition of vessel in national maritime laws is also broad:

- In the United States, the term "vessel" describes *"every description of watercraft or other artificial contrivance used, or capable of being used, as a means of transportation on water"* [8]
- In the United Kingdom, ship contains *"every description of vessel used in navigation"* [9]
- In the Netherlands, ship defined *"all things that are not aircraft, which pursuant to their construction are intended for float and floated"*[10]
- China defines ship as *"sea-going mobile units but excludes ships or crafts used for military or public service purposes, as well as small ships weighing less than 20 tons gross tonnage."* [11]
- The concept of ship, in the Turkish Commercial Code No. 6102 in Turkish law, is defined in article 931/1. According to this, *"Any craft whose purpose requires its assignment to move in the water, has the ability to float is not very small and has swim facility, is considered a ship in terms of this Law, even though it cannot move on its own accords".* In terms of this general definition in the Turkish Commercial Code, it is understood that it is not important whether there is a crew on the ship or not. However, some authors state that the ship should have the ability to move in the water" in times when it has the "swim facility", thus the existence of these

[6] *International Convention for the Unification of Certain Rules of Law relating to Bills of Lading*
[7] *International Convention On Salvage 1989*
[8] United State Code Title 1, Chapter 1 article 3
[9] United Kingdom Merchant Shipping article 1995. Section 313(1)
[10] Dutch Civil Code, Chapter 1, Title 8.1 article 1
[11] Maritime Code of the People's Republic of China, Chapter 1, article 3

two facts together is useless, however the preference of the code maker has been the usage of these two facts together in the definition of the ship.

In the light of the above examples, we may conclude that having a master or crew on board does not appear to be an important aspect of identifying a ship, hence most autonomous ships might be recognized by existing legal and regulatory classifications, and prevailing conventions and national laws would continue to apply to them.

The movement of vessels across the oceans is regulated by a multitude of local and international laws. Unmanned surface vehicles operating in the sea require to comply with a wide range of maritime regulations, including admiralty law that also assumes that seagoing ships are operated by humans. Aside from private international admiralty law, the IMO has established a diverse variety of treaties (HAGGER, 2008).

To be able to respond properly to above, it is important to examine some international maritime law conventions individually. Under this title, a legal evaluation of the ship definitions adopted in maritime law in the UNCLOS, MARPOL, SOLAS, COLREG, and STCW in terms of unmanned ships will made.

A) United Nations Convention on the Law of the Sea (UNCLOS)

UNCLOS is the most comprehensive arrangement in which customary international law existing at the time of its adoption was compiled in many respects and several innovations were introduced, to unify the rules of international law regarding the use of the seas and oceans (Aphornsuvan, 2016). As of 2022, 168 states and the EU are parties to the convention (Sea, 2022). A general definition of ships is not included in this convention. The fact that no legal qualification has been made regarding the ship in UNCLOS is interpreted as it is not intended to impose a limitation on the physical characteristics of the ship (Daum, 2018). The legal vacuum in this direction provides the opportunity to give meaning to the concept of ship individually within the framework of their own fields of interest to different international law instruments.

Article 29, which defines warships, clearly mentions the presence of the crew on board and states that these people are subject to military discipline rules. As a result, it is seen that autonomous merchant ships are included in the class of merchant ships and government vessels managed for commercial functions within the scope of UNCLOS.

Considering what is written above, autonomous ships can be qualified as ships in terms of their legal nature within the scope of UNCLOS. However, it is left to the flag state to decide which vessels will be accepted as ships in terms of their legal nature, as well as the nationality and registration conditions. Indeed, according to article 91 par. 1 of the convention (Robert Veal, 2019).

It has been evaluated that since the shore centre control operator is liable for the navigation, dispatch and management of the ship during the entire sailing in remotely controlled ships, it is aimed primarily at ensuring the safety of navigation at sea in article 94 and since the presence of the captain on the ship is not explicitly stipulated; It would not be wholly inaccurate to state that the shore-based operator can assume the role of captain on conventional ships and be considered a captain within the scope of this provision.

The International Working Group on Unmanned Ships has been established in 2015 through the International Maritime Commission. IWGUS carries out studies on reviewing the current international conventions and revising them in accordance with new technologies such as autonomous ship operations. They published a questionnaire to find out what countries have in activities about autonomous ships. A questionnaire was sent to fifty-two national maritime law societies or associations. In the questionnaire, the definitions of ships in the national legislation of the countries would cover autonomous ships; On remote-controlled ships, whether the operator, if fully autonomous ships, the chief programmer of the ship or a assigned person who is responsible on the paper but not involved in the navigation and management of the ship, can be considered as 'captain' and other personnel working in shore control center as 'crew' , it included these kind of questions. However, member states were asked to make a legal assessment for the provisions in conventions such as UNCLOS, COLREGs, STCW, which at first glance were thought to pose an obstacle for autonomous ships. According to the results of the survey, the majority of the relevant country states stated that there is no obstacle to the evaluation of both remotely controlled and fully autonomous ships as ships in terms of their own national legislation. Thirteen states[12] stated that there is no regulation in their

[12] *Related Countries: United Kingdom, Canada, People's Republic of China, Denmark, Finland, France, Germany, Ireland, Italy, Japan and the United States.*

national legislation that directly or indirectly indicates the presence of the crew on board for the registration of a ship. Five states[13] reported that it would not be possible to register autonomous ships according to national legislation because they do not have crews (CMI, 2021).

The related survey also includes a question about whether there is a possible obstacle to the evaluation of autonomous ships as ships under this convention and whether such ships will be entitled to the same rights and responsibilities as conventional ships (CMI, 2021). Accordingly, although it has been argued by most organizations that autonomous ships are within the scope of UNCLOS and will be entitled to the same rights and responsibilities as conventional ships; it has been emphasized that a series of security problems may accompany it. As a result, port states may not consider the introductory documents related to the security provided by autonomous ships sufficient, or it may be possible to introduce stricter security controls against such ships. Considering the purpose of this convention and the results of the CMI survey, autonomous vessels can be stated that there is no obstacle to the qualification of vehicles as a ship within the scope of the convention. So, the rights and obligations imposed on conventional ships in the contract will also apply to autonomous ships.

As a result, it seems possible to affirm that there is no obstacle for autonomous ships to be qualified as a ship in terms of their legal nature within the scope of UNCLOS, and the relevant provisions examined in this study will not cause problems that cannot be overcome in general. In addition, considering that the coastal states must fulfil in good faith the rights, powers and liberties conferred on them by the convention, their attitudes that prevent autonomous ship operations may constitute a violation of this principle.

[13] *Related Countries: Argentina, Malta, Spain, Brazil and Croatia*

B) International Convention for the Prevention of Pollution from Ships (MARPOL)

MARPOL is a fundamental international convention designed by IMO on the protection of the marine environment and the prevention of pollution caused by negligence or an accident. As of 2022, 158 states are party to the convention, representing approximately 99.01% of the world's maritime fleet (IMO, 2022).

According to paragraph 4 of Article 2 of MARPOL 73/78, ship is defined as;

“The term ship shall mean any vessel operating in the marine environment, including hydrofoil boats, air cushion vehicles, submarines, floating vessels and fixed or floating platforms.”

Considering extent and purpose’s convention, it was preferred not to limit the concept of ship in terms of physical characteristics. When we examine the relevant article, we understand that it is emphasized that any type of sea vehicle that will operate in the sea environment will be considered as a ship, and there is no obstacle to the qualification of autonomous commercial vessels to be allocated to transport goods by sea as ships within the framework of this convention. Secondly, the country on which the autonomous ship is flagged must be a national party headed for the convention. On the other hand, in article 5/4, it is regulated that the parties should not give any privileges to ships belonging to non-party states within the framework of the standards set in this convention.

It is stated that Annex IV on MARPOL, which includes the rules on the prevention of pollution caused by the wastewater coming out of the ships, is generally irrelevant to autonomous ships and its implementation will not be in question for the time being.

Annex V, which includes the rules on the prevention of marine pollution caused by garbage thrown from ships, can also be applied to autonomous ships, based on expression "operation waste collected during the normal operation of the ship" expressed in Rule 1.

Finally, Annex VI, which includes the rules for the prevention of pollution caused by ship flue gases, aims to reduce greenhouse gas emissions and stipulates consumption’s special fuels in certain areas, may not find an application area for such ships, considering that autonomous ships are designed as electrically powered ships.

In summary, most of the provisions in MARPOL do not find application about autonomous ships. Simultaneously, from our perspective, the main point to be considered here is that while describing the term ship in MARPOL convention, there is no statement regarding the presence of the crew on the ship as a determining factor. For this reason, it seems possible to conclude that autonomous ships will be considered as ships under the convention.

C) Convention on International Regulations for Preventing Collisions at Sea (COLREG)

COLREGs is an international convention that regulates traffic rules that ships must comply with at sea. Within the scope of all legal instruments related to maritime law, especially UNCLOS, each vessel is under a duty of care to the other. By introducing certain standards, COLREGs ensure that the duty of care is duly fulfilled by seafarers and thus the safe navigation, and management of the ship (COLREGs,1972). To be able to make navigation of ships safer, COLREGs standardize the equipment that should be on board. As of 2022, 161 states are party to the convention, representing approximately 98.96% of the world's maritime fleet.

According to Article (a) of rule 3 titled *"General Definitions"* of COLREG 72, the definition of ship includes *"all kinds of sea craft that are used as a means of transport on water or are suitable for use on water, including seaplanes"* statement is included. The scope of this definition includes unmanned ships.

It would be appropriate to clarify the definition as broad enough to include autonomous ships. Essentially, the criterion in the conventions that determines whether sea vehicles will be included in the scope of the ship is whether the ship is allocated to transport passengers or goods by sea. In this article, there are definitions depending on the purpose of use or propulsion power of the ships. A "power-driven vessel", a class that includes autonomous vessels, is defined as any vessel propelled by machinery. By machine, any mechanical method of propulsion, other than sails and oars, is indicated. For this reason, it is possible to consider solar-powered autonomous ships within the scope of this definition, as long as the solar energy is produced by a mechanical propulsion power such as a propeller.

COLREG also focuses on a vessel's control status, such as creating a hierarchy of categories, with the most significant being a vessel or vessels not under command or limited in her capacity to manoeuvre. Those classifications impose particular requirements on the vessel and other vessels sailing in its vicinity, included the need that other vessels stay out of the way of a vessel in this category. When we focus on the relevant part of the convention, we conclude that the ship is already controlled from the SCC in a collision avoidance manner, even if there is no ship's captain, so its hierarchy and collision and collision avoidance regulation will be modified accordingly.

Perhaps more confusing is if or how a sea unmanned vehicle might be expected to comply with the well-established principle of international law requiring a vessel to respond to emergency calls from a close vessel. The International Convention on Maritime Search and Rescue of 1979, for example, requires ships to retrieve people in danger, offer them urgent medical or other needs, and take them to a place of safety (HAGGER, 2008). This convention is replicated in multiple areas of maritime law, including the 1989 IMO Salvage Convention. This Convention formalizes an age-old maritime regulation intended to incentivize vessels around stranded or endangered ships to rescue and tow them to port by establishing an automatic right of compensation against the owner. However, unlike requirement to assist people, the Convention does not consider ship rescues a duty in and of itself, and so unmanned vehicles would not be obligated to assist in these kinds of operations. Nonetheless, the Convention presents certain challenges for unmanned ships. The decision to salvage a vessel is an objective one, decided by whether a master has "reasonable fear" that the vessel is sinking or will be damaged (HAGGER, 2008).

Given that COLREGs regulate all or some unmanned surface and underwater vehicles, such vehicles must be developed to meet its requirements, operate safely, and also being visible to other craft. While operating in international waters, unmanned surface vehicles and unmanned underwater vehicles that operate autonomously or under the command of a controller must be programmed to comply with such legislation (COLREGs, 1960-1977).

D) International Convention for the Safety of Life at Sea (SOLAS)

SOLAS has introduced minimum safety standards for ships registered the flag of the contracting states so as to ensure life safety at sea in terms of construction, design, equipment, and organization (SOLAS, 1974). There is not a single legal qualification for the ship, rather, there are definitions that vary depending on the usage area s of the ships. Pursuant to regulation 1 (a), the regulations contained shall apply only to ships engaged on international sea passing, unless expressly stated otherwise. As highlighted by several academical, one of the really significant aspects is inter national technical safety standards, that will almost certainly be applied in the context of this convention, Safety of Life at Sea, and classification society rules (SOLAS, 1974). As for the application of SOLAS to autonomous ships, since this contract is not include a general definition's ship, the absence of captain or crew on the ship is not considered a determining factor in terms of the defined ship classes, and ultimately autonomous merchant ships will be alloc ated to be used in maritime cargos transport, it can be stated that this contract can also be applied to autonomous ships.

According to the SOLAS,1974 regulation titled *"Equipping Personnel",* that ensure the safety of all ships, they undertake to maintain the necessary measures to ensure that all ships are equipped with sufficiently and efficiently manned. Under the title, a safe minimum level of equipment prepared by the administration in accordan ce with the type of ship shall be kept (Tauss Marine, 2017). On the other hand, there is no minimum standard for the number of seafarers stipulated in the convention, and it is regulated that the criteria for this will be determined with the flag states. If the provisions of the convention achieve their purpose (ensure the safety of life at sea), it would be prudent to conclude that autonomous ship operations are in violation of title, based solely on the absence of seafarers on board. However, it argues that as long as it is modified, autonomous ships will not constitute a violation of the relevant provision (Veal, 2017).

Looking at SOLAS Chapter V regulation 15, it is seen that there are a number of principles regarding ship bridge design and procedures, placement and design of navigation systems and equipment. In addition, in order to life safety at sea, the duties as well as responsibilities that must be fulfilled by the bridge team and the guide are listed. With the regulation 15/1, it is aimed to make the bridge design as determined, to place the navigation equipment as required, to perform the situation assessment in the most appropriate way and to ensure the safe navigation of the ship under all operational conditions. However, in accordance with regulation 15/7, the bridge team and the guide ensure that the risks caused by human errors are minimized by using the relevant equipment effectively, and on the other hand, in the presence of such an error, the relevant seafarer "detects the error in a timely manner" by using monitoring and alarm systems and take the necessary precautions.

Regulation 15 is a regulation that covers principles regarding technical aspects such as the design of the ship, of course considering conventional ships. Autonomous ships, in contrast, are ships where the use of artificial intelligence has increased the machine-human interaction and the standards specific to traditional ships have been abandoned significantly in terms of shipbuilding and design. For this reason, in our opinion, it would be more appropriate to act on whether autonomous ships may be appropriate or not, rather than the point that autonomous ships may constitute a violation of the relevant provision. As a result, human error can be considered that the remote-controlled ships within the scope of regulation article 15 follow the relevant provision since they also meet the requirement of the presence of a human who can do due diligence when necessary.

According to titled *"bow and/or route control systems"* in SOLAS, in regions with high traffic density, in restricted visibility conditions and in situations where there is a risk to navigational safety and bow and/or route control systems are activated, Necessary arrangements shall be in place for the ship's steering gear to be switched to manual immediately (Tauss Marine, 2017). In the light of above it seems that titled may create an obstacle for fully autonomous ships.

According to the entitled *"Distress messages: obligations and procedures",* the captain of a ship at sea who receives a distress message from any source that people are in danger, captain assist people in distress or by notifying the search and rescue unit of its movement, as quickly as possible (Tauss Marine, 2017).

In the above-mentioned articles of SOLAS in unmanned ships, there is uncertainty about who will carry out the tasks in question. The mentioned titles should be evaluated and revised for unmanned ships. As a result of this revision, if these responsibilities can be intervened from the shore control center, then according to the SOLAS convention, the ships may become unmanned, and this may not result in any bad results.

E) International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW)

STCW was prepared in 1978 under guidance of IMO and entered into force on an international scale on April 28, 1984. The design of this convention is mainly due to the effort to achieve uniformity among the various legal systems that previously existed in each flag state regarding the training, certification and watchkeeping standards of seafarers. While of 2022, 165 states are party to the convention, representing approximately 99.03% of the world's maritime fleet (STCW, 1978).

According to Article III of the STCW, shall apply to all seafarers on board ships of all flag states (Caputo, A., 2018). In the Convention's Chapter 2/1 titled *"Basic Principles to be Observed during the Navigation watchkeeping"*, the principles to be followed by the ship owners, ship operators, masters and watchkeeping personnel are specified in order to ensure that the parties keep safe navigational watchkeeping (Caputo, A., 2018).

According to paragraph 1 of article 17 of STCW chapter VIII titled *"Watchkeeping Standards"* titled *"Watchkeeping Layouts",* the bridge will never be left unattended. It is considered that it would be appropriate to make necessary arrangements in STCW regarding both maritime and information technology training of seafarers in shore control center for the management and administration of remotely controlled and unmanned ships from shore control center (Caputo, A., 2018).

In summary, as expressly regulated in article 3, the STCW convention regulates the minimum training and qualification standard for seafarers serving on ships in high seas. On the other hand, it is an undeniable fact that there will be different training and qualification standards for the shore-based personnel to be assigned to autonomous ships due to the nature of the work they undertake. Therefore, besides the fact that the current provisions of the convention do not seem likely to be applied to the persons involved in autonomous ship operations, making changes in the relevant convention in this direction would be a more reasonable solution than issuing a new international legal instrument corresponding to the convention to be applied exclusively to autonomous ships.

2.6 Broad Approach to the Existing Legal Framework

When all is going according to plan, there may be no difficulties but if and when an accident happens, everyone here is seeking explanations from the person controlling it, the captain in this means. On a traditional ship, the captain is on board the ship with the crew, we can also ask about the accident. However, on the autonomous ship, this situation is therefore difficult to locate because the captain does not command the ship on the bridge. At that point, required to identify somebody in a similar status, most likely the offshore ship controller at the time. At the same time, he is not in a similar situation - he is not present. So, this is the fundamental or core cause of every legal problem involving autonomous ships. In most circumstances, current rules and conventions will operate, but situations concerning people's presence must be modified. In some of the international conventions reviewed in this section above, the ship is not defined. In the conventions where the ship is defined, the presence of the crew on the ship is not considered to be a determining and required factor. In general, it can be stated that the provisions of the existing conventions regarding the definition of ships do not constitute an obstacle to the definition of autonomous ships as 'ships'.

Regarding the registry port in autonomous ships, the shipowner of the autonomous ship can also manage the sailing of the ship from anywhere they wish. The place where the shore control center is located may be considered more suitable by the ship owners for the management of the ship and this place can be preferred as the registry port of the ship. However, it should not be forgotten that the place where the registry of the ship is located and the place where it is managed can be different countries. In this case, the aforementioned proposition will lose its validity. On the other hand, in the future, with the developments in artificial intelligence technology, it will be possible to manage the ship itself through artificial intelligence from the ship, and this situation will probably be seen as more attractive. The nature of the task undertaken by the shore-based operator on remote-controlled ships essentially corresponds to that of the master on traditional ships. Accordingly, this operator may employ personnel to work at the Shore Control Center while at the registry port, and in case of a special authorization, the legal actions taken by the shipowner may be binding on the shipowner. However, in autonomous ships, there will be no relationship between the physically with ship and/or outside the registry port, the scope of the Shore Control Center operator's authority to represent.

Although it is argued that most of the provisions in MARPOL will not find application for autonomous ships, in the future, these rules may become applicable for the construction and use of autonomous ships with high carrying capacity.

As a result, in this chapter, it has been revealed in detail that there are a number of rules that are predicted to be an obstacle in terms of autonomous ships in many international agreements, especially the STCW agreement. It has been suggested that some of the relevant provisions, through a broad interpretation, may also cover autonomous ships, while others are clearly not compatible with autonomous ships.

CHAPTER 3

Case Study Analysis

The first and second chapters showed us perceptions into the autonomous ships evolving during the period of maritime industry development. Three main aspects were highlighted, namely the innovation in autonomous shipping, the features of the new and possible legal scenario, and the possible effect of autono mous ships on global trade. The purpose of this chapter is to analyse more in-depth autonomous shipping, comparing different perspectives provided by four of the biggest companies implementing it. With this aim, the chapter is divided in the six main paragraphs: the first boring the methodological approach; the paragraph from the second to the fifth inform about the opportunities and threats resulting from the interviews according to the main field of investigation; the last one includes some critical considerations based on the previously showed results. More in depth, the third chapter has been structured as follows:

- In the first paragraph the Research Methodology implemented beside of the AS company involved have been described.
- The second paragraph is focused on strengths and weaknesses related to Autonomous Ships implementation from business perspective.
- The third paragraph attends to the effects of autonomous ships on the maritime sector in terms of logistics aspects and the associated outcomes; financial, social, and environmental.
- The fourth paragraph concerns questions that discuss whether autonomous ships can be recognised in the field of law. It is discussed whether the maritime law and international conventions, which are currently applied to trad itional ships, are also valid on autonomous ships.
- Finally, in the sixth and last paragraph, a future maritime business model and future market scenario have been supposed.

3.1 Research Methodology

The methodology is under the field of qualitative and interpretative analysis, which allows the researchers to deeply explore people's perspectives. More specifically, the applied methodological path includes questionnaire formulation, data collection and data analysis, basing on which the conclusion have been formulated. This research is based on semi-structured interviews, so participants are allowed to freely express their opinions and previous experiences about this topic. The topics discussed in the pr eviously sections have been included in the questionnaire.

After preparing the interviews, companies operating in the autonomous ship sector to which submit issues have been identified.

As indicated in the second chapter, the companies and employees invo lved in the management of autonomous ship projects have been identified and contacted through the references indicated on the company websites. The adopted selection criterion is the identification of companies that have already implemented its own Autonom ous Ship projects.

Two of the four ship companies identified agreed to be interviewed. The interviews have been conducted online (via Zoom, Google Meet, and a phone call, lasting approximately 30-40 minutes). Before conducting the interviews, verbal acceptance allowing to record the conversations has been obtained from each interviewee. Recording has been very useful to avoid missing relevant details. Among the companies that received the requests, four companies responded and gave their full consent to ans wer the questions: Yara international, DNV, Mitsui O.S.K. Lines Ltd. and Massterly AS. Before starting the analysis, the Autonomous Ships projects of these four companies and their activities in the sector are given below.

Table 4. List of Interviewees

INTERVIEWEE	COMPANY	JOB TITLE	DURATION
JAN VAN TIGGELEN	DNV	Leader of Digital Transformation*	60 mins
TOM ARNE PEDERSEN	DNV	Principle Researcher Ship Autonomy Systems	30 mins
JOSTEIN BRAATEN	YARA INTERNATIONAL	Project Manager**	30 mins
JON SLETTEN	YARA INTERNATIONAL	Project Owner	35 mins
PIA MELING	MASSTERLY AS	Vice President, Sales & Marketing	40 mins
TAKERU SUZUKI	MITSUI O.S.K. LINES	Team Leader***	30 mins

Source: Personal Elaboration

* Mr. Tiggelen is working with DNV last 10 years, in the maritime advisory group which is separate from the class, new starting section is called digital transformation and he is the discipline leader for digital transformation. He is principal consultant. Before DNV he worked three years fleet management with technical management of ships. Before that he worked 10 years in Kongsberg group with automation system, navigation system as project manager and head of department. He also was 10 years Netherland Navy as a navy officer, so I sailed sub-marines. Additionally, he is working very closely with Ocean Infinity at that moment, this is that company going to make autonomous or remotely controlled vessels operated from centrally. He added, worked with Yara Birkeland project for some period to support the team. Besides this he teaches at University in Norway called NTU, lecture called digital shipping.

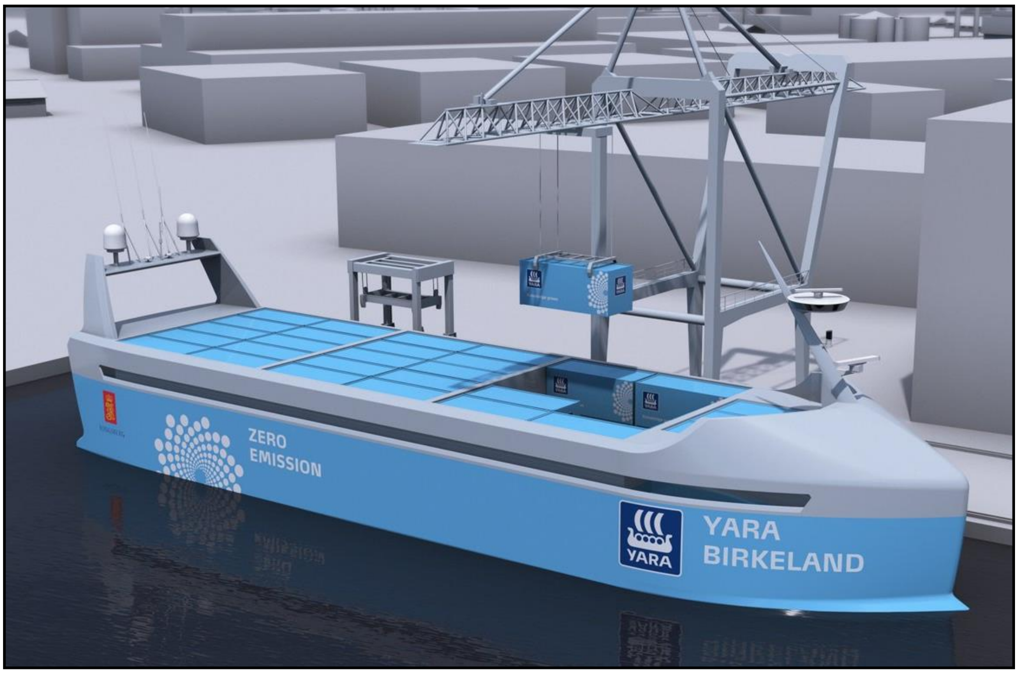
** Mr. Braaten is manager for the Yara International project department for the Scandinavian region. But also, Project manager for Yara Birkeland.

*** Mr. Suzuki is working as the team leader of smart ship operation team and smart shipping division in the MOL Group.

Yara International

The biggest invested autonomous ship "Yara Birkeland", for which the Norwegian company. In 2017, the company present the project to develop "Yara Birkeland," the world's first all-electric, zero-emissions, autonomous container ship, a picture of which is presented in Figure 8. The ship was started to be subjected to container loading and stability tests before the preparations for the autonomous operation. The company aimed to gain experience in the navigation and machinery systems of remotely controlled sh ips capable of coastal navigation and to develop innovations for the production of zero - emission battery-operated commercial ships (Committee, 2018). Some sectoral activities can also be seen as follows mentioned. The autonomous vessel sailed between three ports in southern Norway of the coast. The Norwegian Coastal Administration system in Brevik covers the majority of the region carrying ship traffic. More than a hundred truck drives are required to carriage the products from Yara's facility to the ports of Brevik and Larvik, where it sends its products to customers in various countries around the world, and it is aimed to shift the transportation process from land to sea with this new battery -powered and autonomous container ship. Although the seaway is longer than the highway, it has been stated that it will reduce noise, dust, emissions and increase road safety by eliminating truck trips annually in populated urban areas.

Figure 8. "Yara Birkeland" zero-emission and autonomous ship concept



Source: yara.com, 2021

According to Yara International the marine technology company has multiple roles, such as for the improvement and supply of all key technologies on board, like electric drive, battery, propulsion control systems, in addition to the sensors and integration which are mainly necessary for remote and autonomous operations. It is also stated that since the said ship will burn zero fossil fuel throughout its operational life and its batteries will use hydroelectric energy during loading and unloading, it will have a reducing effect on 700 tons of CO2 emissions every year. Three centers with various operating profiles are intended to manage all areas of operation to assure safety, address unexpected emergencies and exceptions, as well as monitoring the functional operation systems, important decision making, and continuously observing the overall autonomous vessel and its surroundings.

DNV

DNV is a Norway-based organization, best known for being on the front foot of classification society, renowned for consultation activities in the marine sector, and highly experts in assurance and risk management. In addition, this company provides additional services such as qualıty testing, certification, and technical advisory services to the energy value chain, including renewables, oil and gas, and energy management, as well as digital solutions for risk management, asset performance, and safety for ships, pipelines, processing plants, offshore structures, electric grids, and more (DNV, 2022). DNV now is not participated building vessel as a classification society. They are control legislations, regulations, rule what kind of legislation companies need to accept for safety building on autonomous vessels. If a company want to build autonomous ship can help to say how they should build it on safe way also how they test it. DNV is participating as a third party, and they are saying this is correct so we can test vessel and algorithm. They are building simulators, create so fast a lot of scenarios and check this the vessel knows how to react. The company helps ship owners who want to go with right documentation, procedure, insurance, evidence led to allowed to operate. In addition to being consultants, they also pioneered autonomous ship projects in 2013.

DNV launched in 2013 the concept of no crew, zero-emissions for short voyages and introduced the idea of "ReVolt", which is formally presented in Figure 9. According to DNV, the ambitions for the shipping industry are to reduce CO2 emissions by around two third from present levels, decrease freight cost levels as much as possible, and 90% reduction in fatalities in shipping. In the battery systems they want to apply to the autonomous vessels as a pros, there is no direct emissions, high efficiency, low maintenance and for this vessel's charging infrastructure will be charging in on every port stay, average port stays duration of 4 hours, low charge rate but also longer life expanded (Tvete, 2015) (DNV, 2021). As a note the Yara Birkeland project is based on this concept. It was the real support project for autonomous ship, but the Revolt project is an old DNV R&D project from 2012-2014. It has finished. It is understood from the interview that DNV company supports the projects currently carried out in the sector and is on the side of class guidelines, testing, flagged and consulting.

Figure 9. "ReVolt" zero-emission and autonomous ship concept

Source: DNV, 2021

Mitsui O.S.K Lines

Japan is one of the countries that heavily relies on technological advancements in order to progress their economic growth, mostly by governmental efforts in organizing joint projects between Mitsui Lines and Mitsui Engineering & Shipbuilding for the construction of autonomous ships. This team has the aim to provide a valuable technological input for improving autonomous ships by various agents like private companies, governmental and university bodies. This can be attested by the latest autonomous container ships trials performed in Tsuruga Port to Sakai port in January 2022 (Mitsui O.S.K. Lines, 2022). The sailing was managed from an autonomous ship operations control center. Information about other ships and obstacles on the determined route was collected by the environmental information integration system developed by Furuno Electric, and it also performed autonomous berthing and berthing using the berthing/docking support sensor developed by the same company.

Figure 10. "Mikage" during autamed mooring, Jan 2022

Source (Mitsui O.S.K. Lines, 2022)

Massterly

Massterly is a joint venture between Kongsberg Maritime and Wilhelmsen, a technology provider and an innovative shipping company. Company plans to work together to take autonomous ships from research to reality. They provide services for the whole value chain of autonomous ships for customers, from vessel design and approval from necessary authorities through control systems, logistical services, vessel operations, insurance, and possibly financing assistance. They provide a full-service solution by combining the talents, resources, and expertise of their two shareholders' strong organisations (Massterly, 2022).

According to Mrs. Pia from Massterly; They are managers/operators of autonomous vessels, not owners of the vessels. They are in the business of operating these because they believe that the market will grow and they can build a profitable business, but also so that their two owners (Wilhelmsen & Kongsberg) can sell more of their services, products and also develop the solutions of tomorrow for shipping, inspired by the learnings from these projects.

3.2 Analysis & Results of Data

In coherence with the theoretical framework provided in the second chapter, the issues AS related will be described according to the responses received by the various interviewees and their points of view. The companies' sectoral perspectives have been studied through the SWOT Framework of Analysis allowing to identify Autonomous Shipping internal and external factors. This process should lead to the formation of a picture that better represents the situation of the autonomous shipping industry and its potential future developments, creating value for all stakeholders involved. From companies and sectoral perspectives, classifying external and internal factors to perform SWOT analysis technique allows us to understand the status of systems. Furthermore, the SWOT analysis approach may be used to forecast future trends. The method's most notable feature is the analysis of external and internal aspects to generate and organize methods and supportive aids for provision of distinctive strategic targets.

In order to explore and tackle the mentioned objectives, it has been chosen to frame and develop the discussion according to three main themes or aspects of analysis, which can be summarized in the four research keys (or questions) proposed below:

- Could Autonomous Ships represent the solution to sea transportation and logistics process considering their strong and weak points?
- How is the sector able to identify whether autonomous ships are already falling under the same type of legalization as traditional ships?
- What are the main opportunities and threats related to autonomous ship from the company perspective?
- Could the maritime business model be applied to Autonomous Ships to develop future scenario?

3.2.1 Implementation of AS and Their Strength and Weakness side

The first two questions related to the reason for implementing of Autonomous Ships outlining strengths, and weaknesses it related from business perspectives. Following companies answer analysis, it has been revealed that the same points are generally emphasized. As analysed by Mr. Tiggelen from DNV, the biggest reason that evolves the autonomous ships is to reduction of the operational expenditure, all pack costs and reduction of crews expense. If we reduce the crew of the ship, higher will be the profit of the company rather than the crew on board. So, the companies decided to follow this trend having 12-13 people on the board and potentially reducing all pack costs by 40-50 %. There is other reason of implementation of autonomous ship that potentially could be that if look at safety, many accidents and incidents that happened caused by human failure. Indeed, if could develop an autonomous vessel that really has good objective identification and algorithms work, then potentially could reduce these kinds of failures. If the computer manages to make as few mistakes as possible, the system will work accurately as intended. So, it has the potential to improve safety. For example, Yara Birkeland is the reason why created autonomous vessels, also it is an electronic vessel. Implementing was to enable local transport in a safer and environmentally friendly manner by moving transport from diesel-driven trucks on local roads to the sea. But also, to be a front runner showing the way into a greener future. Yara International is importing and exporting large volumes of goods and wants to encourage their freight companies to look for green alternatives.

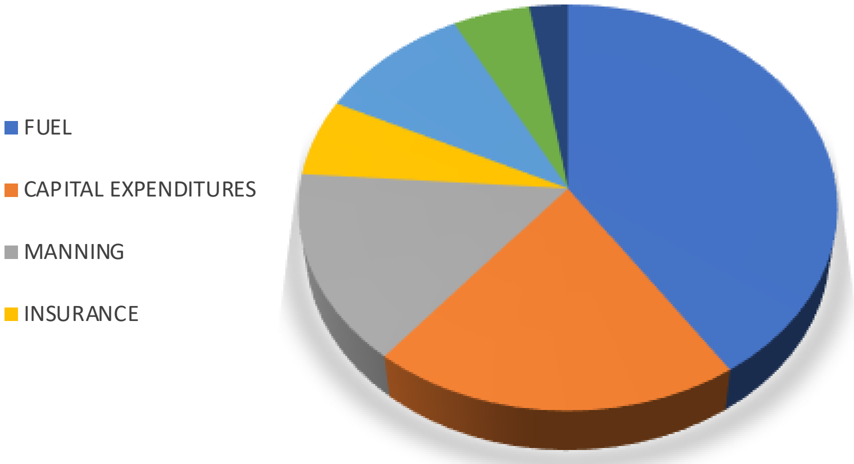
By Yara Birkeland, Mr. Braaten showed that they are able to take the first small step and then inspire the industry to take this further. So, the idea is to reduce environmental impact, this is the goal of the Yara Birkeland project. All other kinds of projects like that for example ocean infinity, want also reduce crew and remotely controlled because they could be totally different from operating. Project owner Mr. Sletten from Yara International, has highlighted these point of implementation of Yara Birkeland, Yara Birkeland had a plan to create a fully electric driven vessel with zero emissions. Furthermore, the intention is to develop the ship to become autonomous and thus un-manned. This gives some potential benefits as, reduced human induced incidents and errors, optimized and repetitive energy and time management, lower operational cost. Yara Birkeland showcases the possibilities of new technology and its potential advantages. The autonomous functionalities will gradually be implemented, tested and when technically verified, it will be subject for approval by relevant authorities, e.g., flag state.

Strengths of autonomous ships, they are sure that autonomous ships would function is intended to the really is working as autonomous ships. A strong point is that one that is working correctly there will know no mistakes for navigation. Another positive aspect can be the cost reduction of crew members. Currently, crew members remotely control the vessel from the operation center but, on the actual ship, all decisions are made by the vessel itself, so we don't have a crew for that. In fact, this is a great interaction that attracts the attention of many companies. The technology can be used for sectors within the industry most fit for such operation. E.g., repetitive sailing routes (e.g., ferries etc). It will also enable a cost effective, time effective and energy effective operations of ships. The technology can also release personnel from night-shifts operations etc. If there is no more need for personnel on the ship, the whole vessel can be rebuilt in a way to function in the most efficient way. Mechanisms that are essential to make the ship habitable for the crew can be removed completely, so the accommodation and bridge will not be of any use to crew members to work on the shıp. This may allow for greater cargo space than conventional vessels. The elimination of the accommodation part may result in a 6% and 5% decrease in fuel consumption and construction costs respectively (Baibhav, 2020). All Autonomous shipping companies interviewed, they mentioned saves personnel expenses. Personnel expenditures generally amount for 30% of a voyage's budget (Researhes Briefs, 2018). MUNIN[14] published an estimated savings of nearly $7 million over 25 years every autonomous ship in fuel consumption, personnel supplies, and wages (MUNIN, 2019). From another research, whereas lower wages reduce by 60%, automation reduces labor expenses by 90% (Baibhav, 2020). As a percentage we can see in the Figure 11, the yearly proportion of cargo costs. Considering the results and the research so far, autonomous ships can eliminate the crew expenditures for the ship's employees, and in fact this is much more important for small ships because the personnel cost of small ships is a very large part of the total expenditures. In fact, looking at Rolls-Royce's report to back it up, autonomous ships are able to reduce the total cargo cost by as much as 20% (Eloranta,

[14] *Marine Unmanned Navigation Through Intelligence in Networks*

2019). For side of the economies of scale, as one set of crew members in a remote operations center can monitor several vessels and it is caused to lower OPEX.

Figure 11. Cargo Annual costs spread in shipping industry



Source: Personal elaboration from Rolls-Royce data

Autonomous ships will play an important role in supply chain management, which Mr. Tiggelen also emphasizes, because autonomous ships will always provide a more active cargo and instant monitoring of the machinery, so that part of the suppy chain will be able to control it easily. In today's world, the supply chain is gradually turn out to be more digitalized and data-driven, assuming that ships might be very effective in increasing the supply chain transparency by gathering voyage-based data throughout their systems. Autonomous ships can provide efficiency and effectiveness in the field of a ship transportation activities. We can say that these activities are: navigation, crossing bridges, berthing or leaving from the port, loading and unloading cargoes, and preparing for the following sailing. If autonomous ships are equipped with latest technological advancements and effective routing and navigation procedures, they are expected to be maximally efficient.

According to interviewees, autonomous ships will reduce human interactions. In this point, I would like to mention about the recent history; as we know covid-19 has recently expanded around to world and all countries significantly affecting the global economy changes then it's brought considerable difficulties. It turned out that the coronavirus mainly spreads through human interactions. The epidemic is also having a huge challenges on the shipping industry. Because the virus is highly infectious and spreads mostly through human contact, when looking at autonomous ships, there is less human interaction than the ships used now or there is no human interaction so it can be a solution to prevent a bit of infectious diseases that can be transmitted from person to person by any contact in the long term. So, autonomous ships may be a viable and safe solution.

At the same time, Autonomous ship presents some weak points. So, if the vessel in the middle of transit gets into a technical problem so what do we do? This is a really big challenge since it's hard to assign a person to solve problems and safety restore the normal operating capacity. Another challenges are the level of trust of all the people involved on the autonomous ships' function. At that point, legislation is important to travel with autonomous ships. There is no rule or regulations for IMO that open up to national travels with autonomous ships. There is a kind of code called MSC.1 1455 (Guidelines for the approval of alternatives and equivalents by IMO) which is improving innovative technology so this is a kind of process you can get a proof of a new system. Also, another issue is the assurance of provision of the autonomous ships insurance. What would be the cost? How will the insurance company react to being willing to insure the vessel? The legislations are not yet ready. Still quite challenging to define the scope of the design and development of autonomous ships as long as there are no clear regulations. The cost picture for such projects is therefore quite uncertain. According to the Yara International Company; with the rapid progress and use of technology, there is usually the risk that individuals may be unable to integrate better into their new environment and complete their everyday duties. As data collection and analytical abilities develop more, it is crucial that we educate these skills to new personnel. In many industries, this has been overcome by measures such as skill development, training, and professional development. Furthermore, the shipping sector faces difficulty because the majority of work and maintenance is done manually in European shipyards, which has seen a significant rise in advanced systems and drives autonomous ships to keep up with the growing and often challenging technological levels which is becoming increasingly difficult over the next years (Cicek, 2019) (Perry, 2005). With the decreased need for expert workers aboard the autonomous or semi-autonomous ships, ıt ıs expected to have lımıted opportunities and prospects for advancement for crew and vessel operators. This risk to employment is also present in ports adopting comparable technology because they may create issues related to mismanagement of employers and workers interests. Also, training employees to operate vessels in disputed locations is challengeable (Baldauf, 2018). Coordination between human and autonomous vessels will be crucial in the meantime to limit the risk of accidents in common zones. When it comes to setting up and adopting new technology, there are both direct and indirect expenses to consider. Although many technologies have gotten more low cost in recent years, there are still limits to what businesses may invest in (Ellingsen, December 2019). Businesses that bravely invest in the above-mentioned solutions can easily cope and adapt to the varying market and technological demands on digital technology (Koren, 2010). In nowadays' competitive market, a company's ability to decrease ship development time might be critical to its profitability. Digitalization may be a growth facilitator that can fuel the future technologies of ships; "but it must be viewed as a means to a purpose, not an end in itself" (Ginters, 2019). There are challenges to obtaining these pieces of equipment when implementing technology (Koren, 2010) . Regardless of the potential benefits to the companies, they also face many obstacles to the technological transition: the elevated prices of primary materials, operational costs, general maintenance, teaching and training workers to learn and operate the system are all complex tasks.

3.2.2 Logistic Process Perspective & Technological Aspects

The third question was about understanding the information in the industry about whether autonomous ships could improve the future maritime logistics, and the outputs were as follows. All companies agreed and highlighted the point autonomous shipping can lead to better logistic process. Their example is mentioned in the ferry companies. That is, the schedule of operations is much more reliable, the precision in repetitive sailings, so an Autonomous ship will start the vessel on time to better manage the time and the travel on the route so more reliable and potentially positive. If we think of supply chain management from an international perspective, it is more necessary that information is flowing on the whole supply chain and when you create autonomous vessels, they will connect with the central data, all information is much better flowing centralized so, it should have a positive effect on all logistic processes. According to the opinion of Mr. Pedersen, we may connect autonomous shipping with autonomous systems onshore, that could be cranes, trucks etc., to ensure all necessary resources are available at the correct time to minimize waiting time, emissions etc. Autonomous shipping is only one piece of a puzzle.

The content of the questions numbered five, six and last question directed to the interviewed companies mostly lies in the technological aspects and replace about autonomous ship to currently conventional ship. The question was whether they are developing the autonomous ships on already existing ports. The answer to this question will really be very important for all maritime industry because it is predicted that apart from developed Scandinavian countries, European countries and Asian countries, whether these ships are available or not will also be related to the port where the ship will dock. Yara Birkeland is built for the specific ports where they operated autonomous cranes at least they intend autonomous cranes in Norway. They have a system onboard to mooring so it can be autonomously moored. There is no need of people to moor the vessel. For instance, ASKO intends to build similar technology in both aspects. The question is how it will be in the future? If autonomous ship joins in international trade and visit many different kinds of ports, there is not so much work done about it at the moment. In the first step, they try to do autonomous ships from one country to another.

In case this is not possible, crew workers will take the ship out of the harbours, into the sea and allow the AS to proceed on the course autonomously. At the end of the voyage of around 10-15 days, crew members will again retake the Ship from the sea to the harbour. In the future they can make common harbour instruction so operations can be the same depending on the kind of vessel it is container/oil since they need different kinds of loading and unloading systems. DNV Group believes these autonomous ships can build for current ports but not goals autonomously port. DNV doesn't have any projects for autonomous ships ports, but it has some projects for smart ports at that moment. The first step is autonomous ships than an autonomous port. Yara Birkeland and the concept here is that it generally can relate to current port systems. Implement new technology, it would be easier to implement if no dramatic changes are required to the existing infrastructure. A giant step in technology would be hindered if the whole world around it also would have to change. According to the Mr. Suzuki from the Mitsui O.S.K Lines, they are thinking if it is unmanned vessels, so it needs to supported from shoreside for now.

As stated earlier, there are obviously elements within the functionalities for autonomy which can be used in conventional ships. Systems or technologies need to replace the people all of the ship. So, what the people doing on the board need to replace this technology. According to DNV company, on the ship have main places to replace. On the bridge: replace in the captain. On the technology perspective it has to sensors, so can do objective technion and can see what happening all round the vessel then you can identify. So, we need to replace of captain eyes. But also, intelligent system needs to replace brain of the captain. Captain is looking and he is acting, analysing what is it he knows regulations, rules how he moored, monitor vessel after that he makes the decision, he is controlling the vessel. We need to develop technology for collision avoidance. It can modify this all kind of the vessel, we can install a kind of decision support to existing captain to that have captain on bridge, but the system could advise the captain, as a system reports that seen this what can do for next step based on regulating advise to this and captain can choose to do this or not in the control center. This system can also apply current ships, when raise the alarm, one person come to bridge. This can be solution for all of the kind of vessel.

Also, other important part of ship is engine room and everything on the engine room has to be automated so autonomous shipping company don't need any people. They can give alarm for temperature and pressure. Because also chief engineer will not be on board. As they mentioned also, it is not type of technology. It is difficult to apply these systems to current built vessel but when you build one ship as an autonomous ship it will be easy to apply these technologies. Adaptation is easier then already built vessel. If this technology has some problem, we can transfer it to smaller ship like ferry and barge and can continue to use.

Specified in the question that which ones it could be more effective and why DNV company perspective has given that it will start where they have best connectivity for example, ferry industry in the Norway they are going are point to one point 2-1 hour transit the same route all the time. They have connectivity so they have data to transfer between the ships and the center transfer without any problems. It is very short distances. If something happens, it is easy to give help. If the ship going Atlantic giving help really difficult maybe it is not good connectivity. It will start ferry industry, offshore industry (shore-platform), inland shipping. However, inland shipping is more crowed, can be challenging so it is difficult to create algorithms. In addition to small USV's carrying AUV's or ROV's, naval vessels (e.g., mine sweepers, special vessels (e.g., fire vessels in port), domestic short-haul and regional short-sea shipping is the most effective sector to develop autonomous vessels due to good connectivity, local/regional regulation (not IMO) and high cost of crew (abt. 50% of OPEX). Container vessels with fixed ports are easier to automate than general cargo vessels in tramp shipping and with diverse cargo. Passenger vessels are more challenging to operate unmanned due to potential evacuation of passengers.

In the last question about whether autonomous ships could completely replace current conventional ships in the future, the thoughts of both companies were almost the same. View from Mr. Braaten, he is not believing complete replacement he does not foresee. But there would be areas where autonomous vessel would have a clear advantage and fully replace traditional ships. According to Mr. Tiggelen, between 10-20 years autonomous ship will improve, we will have autonomous navigation. Its advantages really big you reduce crew cost, company has huge advantage but if we look at 50 years, he mentioned pretty sure autonomous ships replace active control on centre pretty sure will come for near future. Opinion of Mr. Pedersen, he thinks this will take time, and will not replace traditional ships in near future. He believes autonomous ships will come, but he does not think it will completely replace traditional ships. Ms. Meling does not thinks deep-sea vessels (e.g., crossing the Atlantic Ocean) will be unmanned in a very long time, if ever. This is due to poor and costly connectivity, the need for maintenance during transit, the crew cost in % of OPEX is less than for short sea / domestic shipping and the IMO regulations are slow to adapt. However, there are smarter and safer ways to operate a deep-sea vessel, with reduced crew, more automation, anti-collision, e-navigation and support from shore based-crew and "expert-in-the-loop".

3.2.3 Legislation Perspective

The fourth question and the sub-headings of the fourth question included questions that may or may not be included in the current maritime law and existing conventions of autonomous ships. From the answers to these questions, it is aimed to get information and thoughts about the legalization of autonomous shipping companies that are interviewed with the sector. As understood from the interview, all companies confirm that an autonomous ship can be defined as a ship. According to DNV Company, it always has to be the captain who is responsible for the vessel. This captain is on the board and can sit in the control centre. Mr Tiggelen thinks all will in the future create legislation for autonomous ships, but this is not going fast. They are working on it, but this process takes 5-10 years. But national borders for example Norway, government and maritime authorities can be fully authorized to use autonomous ships. Autonomous ships not depending on Norway's national law. Each country can confirm their side. But if autonomous ships or traders want to move between countries, they could be required to have international legislation. They are working on this but all new territory so industry and technology knowledge pushing hard but legislation is slow. There always be a person responsible for the vessel. An autonomous ship or remote-control vessel cannot think of any responsible person. Physically one person owner of the ship. So, according to the ISM code for safety one person needs to be responsible for also legislation. This captain is located in the control centre; this captain will be responsible for the vessel. In the control centre, a captain cannot work all 24 hours. They need to be shifted. The control centre has a captain and people who work for him to monitor to vessel. So maybe the captain is responsible, he has an operator, maybe monitoring 2-3 more vessels but each vessel has a very high technical level and can take care own safety. So, the vessel is programmed to go A to B, and it has all kinds of technology that can all time monitor its own safety and if something happens the vessel autonomously can go into reach minimum risk conditions. For example, if something happened vessel is still alive or raises an alarm. When raising the alarm somebody in the centre can take control of the vessel. Always it has to be a captain or one person responsible and one person responsible for operation so who decide where the vessel should go and also one person from shipping company who responsible legally as the owner of the vessel. In case, a big accident happens somebody needs to pay the consequences, which would be the shipping company, or the owner of the vessel. According to Mr. Pedersen, this is a difficult theme and thing that are still under development. The vendor will get more responsibility. Some argue that also Class society will get more responsibility. Also, an autonomous vessel does not necessarily mean unmanned vessel. One could still have people on board, even though the vessel is autonomous. It could be that when a situation occurs, then people on board need to take control. As already mentioned, autonomous does not mean unmanned. Also, one could foresee that a shipping company operates several vessels through their shore control centre, then they are still the responsible party. The captain still has the legal responsibility although he/she performs their duties from a SCC. The captains will work shifts on shore, but the entire SCC personnel are trained and certified to operate the fleet.

3.3 Opportunities and Threats

In this paragraph, we will see more in analysis detail the opportunities and threats in the emergence of autonomous ships based on the statements of the firms interviewed. We separate this section from the others since believed it was significant to compare opportunities and threats with the specific situation of the autonomous vessels. Opportunities and threats mentioned in this section are blended by revealing the thoughts of the interviewees' companies. There are strengths mentioned in the previous section that come with autonomous ships, but when we look at them, we see that they also support opportunities. First of all, autonomous shipping companies mentioned that as we talked on the upside improves life safety and allows more effective use the space of the ship's hull and fuel capacity design. In fact, this is a great interaction that attracts the attention of many shipbuilding companies. Over a 25-year duration, a three-year research effort conducted by MUNIN estimated savings of more than $7 million in fuel consumption, crew supplies, and wages per autonomous ship (O'Brien, September 2018). It will also enable a cost effective, time effective and energy effective operations of ships. When humans are no longer necessary on board, the entire vessel may be significantly redesigned to improve efficiency and effectiveness. We can think about structures that were previously requiring on the building of the vessel processes liveable intended for the crews might completely remove. The deck house, which now stands beyond the deck of ships and holds the crew while allowing to navigate the boat, would be obsolete. Additional opportunity recognized by companies of the idea of remotely operated and autonomous ships are that they may be developed with a extended cargo carrying volume due to the elimination of crew accommodation. This might provide for additional cargo capacity, allowing loading processes easier than conventional. Once automation converts a feasible option, the industry will not just produce the same cargo vessels that they do now, without the crew. Crew reducing occurs more commonly than total crew replacement. It may be thought that the emptiness caused by the decrease in the number of employees on the ship will replace robots in the coming years. We already know that there are robots used on the ship (as I explained in the second chapter), but now these robots are produced for emergencies, to activate in case of any danger. Humans may need to remain in the loop until robots are sufficient to fix engines or do different normal on board chores. As Jon Walker mentioned his sentences; given the robotics applications for learning complicated physical tasks such as building, manufacturing assembly, and more, we may expect robots crews to accompany autonomous ships in the coming decade (Walker, 2019).

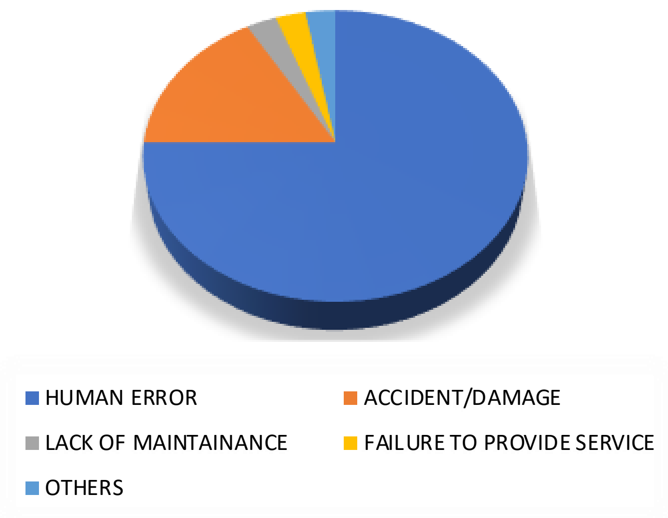
Opportunities that give on cheaper way can operate so it would be cheaper to transport the goods, reduce the cost, and more safety. Reduce the fuel, it could be that autonomous navigation can more effectively control more fuel consumption, but it can be done little better by computer. According to DNV Company, for example Ferry companies in Norway that using computer to control the vessel for auto docking and auto transit. They think that they in the future the system can more fuel-efficient control vessel then captain can but at the moment it is not the case. But expect that by improve the algorithm, artificial intelligence, and kind of learning, they can do more efficient. If it short distance then they can have batteries then maybe one hour transit they can use batteries but as long as compaction engine it is not so easy to go for autonomous because you need crew, people to monitor to machinery part. Let say big container liner that going transit on long distances could be on the potentially future.

Mr. Sletten from Yara International Company highlighted reducing human errors and maritime accidents as all interviewees from their project Yara Birkeland. It had a plan to create a fully electric driven vessel with zero emissions. Furthermore, the intention is to develop the ship to become autonomous and thus un-manned. This gives some potential opportunities as, reduced human induced incidents and errors. Sea craft safety regulations are unlikely to have seen the same level of debate and invention as self-driving vehicles or trucks. Many of today's safety rules and alerts in self-driving cars mentioned "forward collision warning" if similar emerging moment use investigated to autonomous ships, so might be able to envision a scenario in which self-driving boats are almost universally safer for people and cargo. Remotely operated and autonomous vessels are projected to minimize the risk of human errors or accidents, as well as the risk of injury or death to crew members as well as danger to the vessel itself. Autonomy can certainly improve safety aspects at sea as there are now about 70% of all incidents due to human error and fatigue. Systems and functions developed for autonomous operation can be support functions also for manned ships and improve operational reliability, safety, energy consumption etc. According to Mr. Sletten can say as strengths of autonomous ships; reduced human incidents and errors, lower operational cost, optimized and repetitive energy and time management. While analysing the interviews, I would like to crown human error, which is a subject that the interviewees put a lot of emphasis on, with a recent example here. Ever Given MV, one of the world's largest container ships in the sector, stucked in the Suez Canal in March 2021 due to serious winds and stayed stalled for some days and stopping traffic in all directions. As a result of this a total trade loss of almost $54 billion for the Japanese-owned ship (Koustav, 2021). The grounding of the large container vessel in the canal was caused by technical or human error, according to Suez Canal Authority Chairman Admiral Osama Rabie "Suez Canal: Vessel block might be the result of human error" (DW News, 2021) Human error is the cause for many sea accidents on the shipping industry. Autonomous ships may potentially be a realistic option in this situation.

Aside from more safety, the potential of minimizing human errors and, as a result, lowering costs associated with accidents and insurance. Human mistake accounts for around 75% - %96 of all mishaps in transportation business, according to Allianz Global Corporate & Specialty (Walker, 2019). These accidents are the leading source of liability loss.

When look at another source, human error has a significant effect on transportation, as seen in Figure 12 human error is the cause of 96 out of every a hundred accidents (Rothblum, 2022). Unmanned vessels carry the potential decreasing human errors and, as a result, lower charges correlated to accidents and insurance. Enabling greater operational and process optimization for autonomous shipping (Walker, 2019). So, we can come that autonomous ships will be a reasonable solution regarded to human error.

Figure 12. errors in maritime industry



Source: Personal elaboration

Another opportunity maybe we can say solution would be to prevent pirate attacks. Due to pirate attacks, some merchants prefer routes that can take longer delivery times, and considering the pirate attacks, they cause an extra cost for the company, as they do not pass-through dangerous areas, but if they do, they put human life in danger. In the case of autonomous ships, pirate attacks will not be seen as a threat, because there will be no one on board to take hostage and demand ransom. Autonomous ships will be less attractive to pirates, since they will be more sealed, and pirates are still interested in the crew and their valuables, and if crew is not on board, it becomes less interesting for them to attack an autonomous vessel. Another thing is that autonomous ships is planning to build in such a way that getting on board much more difficult. Today, conventional ships have a flat deck because crew have to move on board, if autonomous ships with not physically crew on board, shipyard will build ship's deck as hydrodynamic making it difficult to get on board. So, if the pirates try to get the control into the ship, autonomous vessel automatically shuts down and becomes inaccessible so to control it getting difficult. Furthermore, hostage crew is a significant motivation for pirates. That motivation is misplaced without the crew. Overall, physical attacks will loss attention less effective and less attractive to pirates. When we mentioned there is nobody on the ship, it seems difficult to threaten or take hostage and piracy likely to be decreased or eliminated. So, also kidnapping threats for the seaman is a major motivator for piracy.

Another opportunity factor that was somewhat expressed during the interviews was the seafarers. Analysing the situation of them when more mechanical and electrical systems are placed on vessels, vessels become much more complicated, requiring to trained specialists to keep vessels working. Simultaneously, sailing as a profession has become less attractive, with fewer employees stay months away from home and family. Remote and autonomous vessel management allow the transfer of positions requiring advanced education and skills to ports of call or operational control centers on the land side, making such professions more attractive to new people joining the sector. Although that adoption of Industry 4.0 and shipping 4.0 was accepted, it created certain difficulties. One instance labour market, where expected automation would replace people. People will not be out of job, and new industries will arise. In fact, these vessels still require human controls to operate. Workers and seafarers need to attend training and improve experience in this industry. Besides, the introduction could replace some jobs at an equivalent time, however, it creates a new set of jobs. Crew could reduce with technology advances on board, however there may be significant extra job opportunities onshore that need nautical knowledge. But also, one of the biggest advantages, more attractive jobs for seafarers who want to work 8-hour shifts and return to their family. Importantly, automation, as emphasized by Guy Platten, Former Secretary-General of ICS, will have an impact on a variety of domains within IMO's authority (ICS(International Chamber of Shipping), 2018). It will also create new possibilities that do not present now, but considerable work needs to be done, specifically on the legislative front, to address about the effect of autonomous ship on mariners globally. As a result, reskilling of labor will be required.

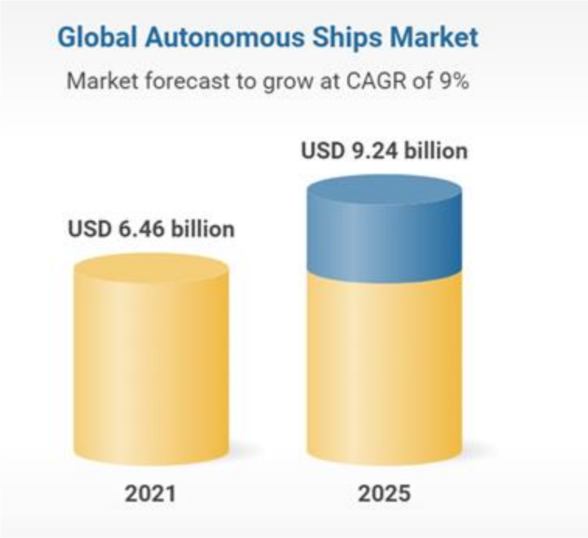
While analysing the interviews, autonomous ship threats emerged. In fact, it has revealed that the more opportunities it has, the more sectoral threats it has. Despite operational savings, so will be a significant capital expenditure on initial technological investment, particularly beginning phases of its process. Existing ships infrastructure may potentially be incompatible with an autonomous ship. In addition, a shortage of staff makes it extremely difficult to keep moving parts moving on extended journeys, and failures can cause substantial delays. This procedure will most likely take a long time to complete since new laws governing the operation of these autonomous vessels will need to be enacted. The capital required for this investment is substantial, and some organizations may decide to stay with the traditional policy of recruiting crew members for vessel operating. Because autonomous ships must function without any crew onboard, if there are any failures or problems in machinery, the ship must return to land or a docking station to be fixed and made suitable for sailing. Autonomous ships must be outfitted with extremely strong and capable GPS monitoring and control systems that can be utilized even in extreme weather conditions. There are big threats sure for people who work in the industries. They are potentially loss their job. The sector will loss important knowledge competency about sailing vessel because if they looking shipping company on shore, they are depending people super intensive on shore, they have experience from sailing on ships, competencies being lost. Also, if we look at industry making distance like navigation, automation systems all this. All be done, by people have been sailing know what happens on the ship so also this companies (non-producers) they need the people with sailing ship management competence. One of the significant threat is that lack of trust in autonomous systems. No guarantee of greener and safer waters, limited job opportunities for sailors, search and rescue operations at sea jeopardized, possible threat to all manned ships, smaller boats, fishing vessels, and other vessels in the area, safety and security difficulties for vessels in conflict zones. One of the biggest threats seen as public opinion could be common threat. If autonomous ships happened accident and people killed. That could be big public pressure about not accept autonomous ships.

3.4 Potentially Future Market Scenario and Maritime Business Model

The following companies are major players in the autonomous shipping market: Yara International, DNV, ABB, Rolls-Royce, Kongsberg Group, NYK Lines, Mitsui Holdings.

The world market for autonomous ships is expected to expand cumulative annual growth rate of 13.7 percent from $5.68 billion in 2020 to $6.46 billion in 2021. The increase is primarily due to companies resuming operations and adapting to the new normal while recovering from the COVID-19 impact, which had previously resulted in restrictive containment measures such as social distancing, remote working, and the closure of commercial activities, resulting in operational challenges (Research and Markets, 2021). At a CAGR[15] of 9%, the market is estimated to reach $9.24 billion in 2025 as we seen on figure 13.

Figure 13. Market forecast to grow at CAGR of %9



Source: (Autonomous Ships Global Market Report 2021, 2021)

Furthermore, demand for autonomous vessels is increasing because of greater automation, and rising desire to encourage safe and efficient maritime industry. Overview of the statistics, AI has been developing the logistics and transportation sector performance by %90, increasing yearly revenue by up to 0.45 euro trillion (Baibhav, 2020). These will very certainly increase demand for autonomous ships in the future.

[15] *Compound annual growth rate*

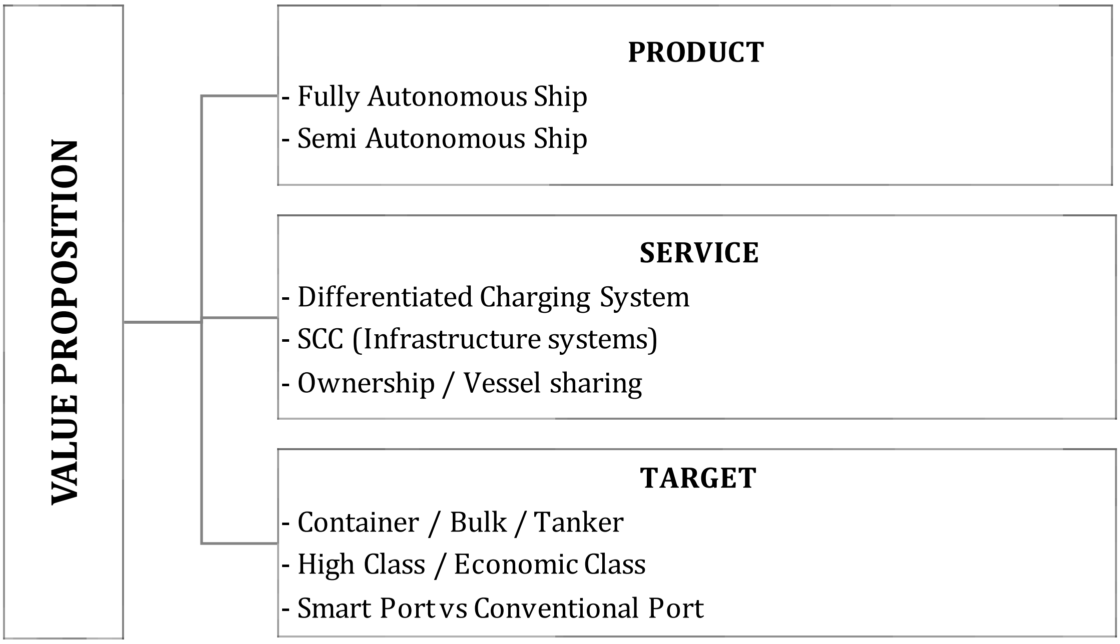
Long-term repercussions reach well beyond the shipping sector. Lowering transportation costs might lower operational costs throughout the board and begin several of the entering market opportunities. Low-value products were previously not so much worth shipping might convert profitable. The worldwide autonomous ships market is growing because to increased ship operating safety and increased demand for cargo transportation through sea. Moreover, the network's complexities and possibility's exploitation through limit market growth. On the contrary, an increase on the maritime safety standards and expectation trend of automation seaside carriage will create novel opportunities for participants that on the market. When we look at near past, pandemic and lockdown situation on the world led states to utilize remote working operations. Nevertheless, slowing up to world commerce have affected demand for autonomous vessels. Due to a manpower shortage, the pandemic effects the global trade and pushed to complementary producers so transportation industries to focus on artificial intelligence. Meanwhile, by governments announcing a lessening of restrictions, and world trade, this market is predicted to recover. The world autonomous vessels market is divided into four sections: autonomy level, vessel type, component, fuel type, and geography. The market has been segmented into semi-autonomous and fully autonomous divisions based on level of autonomy. During forecast period, the fully autonomous group expected to exhibit the highest CAGR of 27.5 %, therefore, the semi-autonomous segment led global in 2020, providing for more than 90% of total market volume (WorkBoat staff, 2021).

The business model is how a company creates value for itself while delivering products or services to its customers. So, we can apply any company from the world's largest to two-person start-up to business model. Despite the probable benefits of autonomous vessels, they are expected to have obstacles in entering the shipping market, as with any other sustainable technology. Considering that the shipping market is divided into four main sections, these are; the freight market, the sale and purchase market, the new building market, and the demolition market. It is obvious that all segments will be affected by this initiative because autonomous ships will exist throughout the production cycle. One overlooked obstacle to market penetration and that sustainable technologies undermine recent corporate operations that rely significantly on usage of fossil fuels, oil, and gas (Mark W. Johnson, 2009). The traditional shipping industry is mainly reliant on fossil fuels, and companies have an interest in earning from unsustainable business methods. Whereas new applicants expected to stimulate adoption of sustainable technologies, the largely on the size of sustainable technologies to the market, as well as competition from powerful players, often significant obstacles. Furthermore, the production process is required specialized skills, and know client partialities intended for sustainable technologies frequently changed from those of typical technologies, then just predicted environmental benefits not occur in widespread customer acceptance. Nevertheless, as previously discussed already, autonomous ships will benefit in a variety of ways, both economically and socially, furthermore, to dropping shipping emissions. Therefore, business models for autonomous ships may be conceptualized using three fundamentals: value proposition, value chain configuration, and revenue model.

With innovations implemented in business models, the shipbuilding industry might occur new sources of value for its customers whereas maintaining sustainable technology adoption. For autonomous ships penetrate into the market, providing additional customer benefits, namely, qualifying the higher preliminary investment equated to purchasing a conventional ship, is a crucial factor. Although business models are quite complex in their own characteristics and there are many different conceptualizations, we can try to explain the elements of business models for autonomous ships based on three main aspects.

3.4.1 Value Proposition

Figure 14 . Value Proposition Component of Autonomous ship's Business Model



Source: Personal elaboration

Value proposition means that basicly summarizes why customers should choose your product or services. We can divided autonomous ships to fully autonomous ship and semi autonomou ship from side of the product identification. In terms of fully autonomous ships, such ships can navigate from one point to another completely on their own and can do this without the assistance of any crew. In some emergency situations, when the shore control center is notified, the team working there will be in a position to take care of this problem. But when we take a look at semi-autonomous ships, they are always under surveillance and control by the shore control center and in some cases even a certain part of the crew must be on board. Fully autonomous ships have a futuristic structure based on the interviews and research conducted so far. No matter how short distances it may be used, it is currently unlikely to be used on long ocean crossings or without any human intervention. The designs made on the ship reveal a completely futuristic shape as well as the traditional designs that are present now. The futuristic nature of fully autonomous ships allows for a much developed level economies of scale in transporting goods and energy efficiency. If the design that is applied to conventional ships is applied to autonomous ships, it will be inefficient for them in terms of cost, energy and capacity.

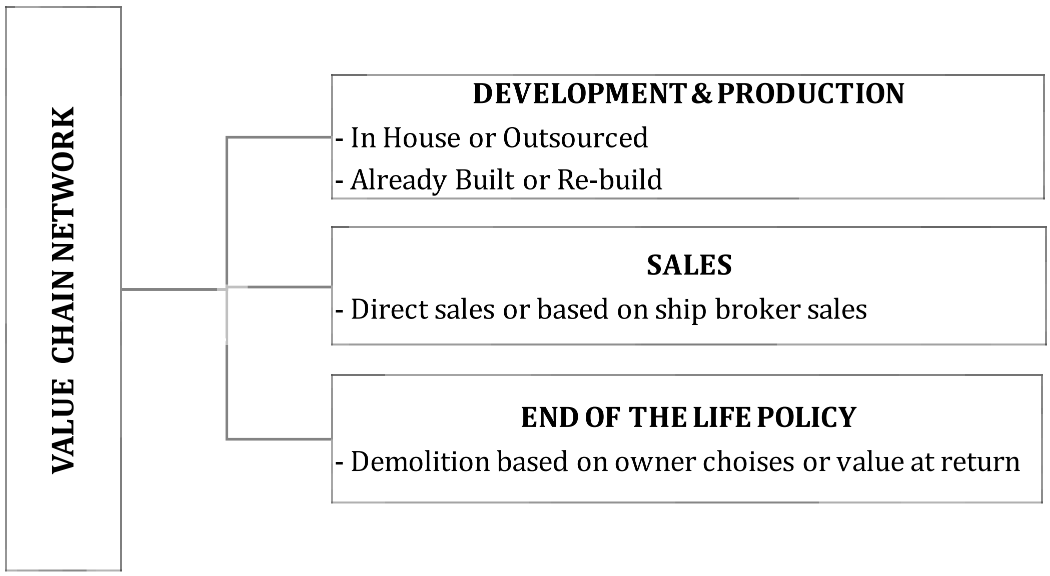
When we look at the service, we see a differentiated charging system, shore control center. Autonomous shipbuilders, now and in the future, should definitely focus heavily on service content. Looking at the current status and production purposes of autonomous ships, although it is expected to be used in short sea shipping in the first place, technologies such as backup batteries, activation of solar energy, and storage of solar energy on non-sunny days should always be in place when opened to long sea sailing. At the same time, autonomous shipbuilders should ensure that there is an continuous operation in battery charging stations for autonomous ships built on the basis of electricity and in shore control centers for semi-autonomous ships. One of important issues to consider is the chartering of autonomous ships. Whether this may continue to be the same as currently applied to conventional ships remains to be considered. In the case of autonomous ships, autonomous ship producers can provide their customers who want to acquire the ship with the right to share ships, which is very advantageous, instead of just providing ownership. Ships can be chartered by time or voyage and the customer can pay per use, just like normal ships at the moment. The only difference is that from the current situation, this will be offered by the autonomous shipbuilders, that is, it seems that it cannot be offered by the ship owner. One of the essential parts of the business model is the determination of the target segment. Based on the data obtained from the interviews and the research done on the previous chapter's, we can consider the business model target segment for autonomous ships as container, bulk and tanker ships. Once the target segment has been defined, companies may consider providing the autonomous ship category as high class and economy class. Despite this distinction, there should not be any difference in terms of high safety. Only high-class autonomous ships can provide better conserved energy efficiency and will be more expensive than economy-class ships. This will enable market leaders in autonomous shipping market and stakeholders planning to enter this market to penetrate more easily. According to the information analyzed in the interviews, this important issue should be taken into account when the manufacturers and unmanned ship companies analyze and apply their strategies whether autonomous ships will be suitable for existing ports or developed smart ports.

When we look at the important points in the value proposition part of the business model, we can think of two different company structures and their activities, the incumbent businesses, and the entrepreneurial businesses. For the incumbent businesses, we can say that they try to integrate newly developed technology into their existing business models.

But on the other hand, for the entrepreneurial business, these companies create a new business model with new technology. While incumbent companies are more limited in their business modeling, entrepreneurial companies are not affected by any limitations. Let's examine the three sub-headings described in the title of the value proposition from the previous analyses. The incumbent business may prefer autonomous ships as semi-autonomous rather than fully autonomous because it is not a new business model against all the innovations like entrepreneurial companies, but only for a model that already exists. At the same time, based on the service content, incumbent companies may move forward to incorporate differentiated charging and battery life into their business models and traditionally become ownership of the ship. But instead of integrating the version, which are entrepreneurial companies, they can use shore control centers, which is something that is developed and unique, and advance their business models in that direction, and they can put forward a business model that is outside of the traditional and can be shared and used by both the ship owner and the ship. In fact, this can turn out to be a much more profitable business in the long run (both voyage, time chartering, but also ownership). As a target segment, incumbent companies may want to focus on only one of the three type cargo shipping (container or bulk or tanker), while entrepreneurial companies may want to reach all three type cargo shipping at the same time. But we may not think that the target for incumbent companies may reach with a few changes that they integrate into their traditional business models may be high class. However, entrepreneurial companies have reached three main cargo shipping types and they have already invested too much in autonomous technological ships so the class reached may be the economic class, and this is a lot of cargo at once. It provides quick transport to many places, so it can be circulation for transfer from point A to B. Semi-autonomous ships in incumbent companies may easily be accessed to the ports currently used and the ports to be built for full autonomous ships in the future, but an entrepreneurial company's target segment may reach through smart ports if only the shore control center will be used as a basis.

3.4.2 Value Chain Architecture

Figure 15 . Value Chain Architecture Component of Autonomous ship's Business Model



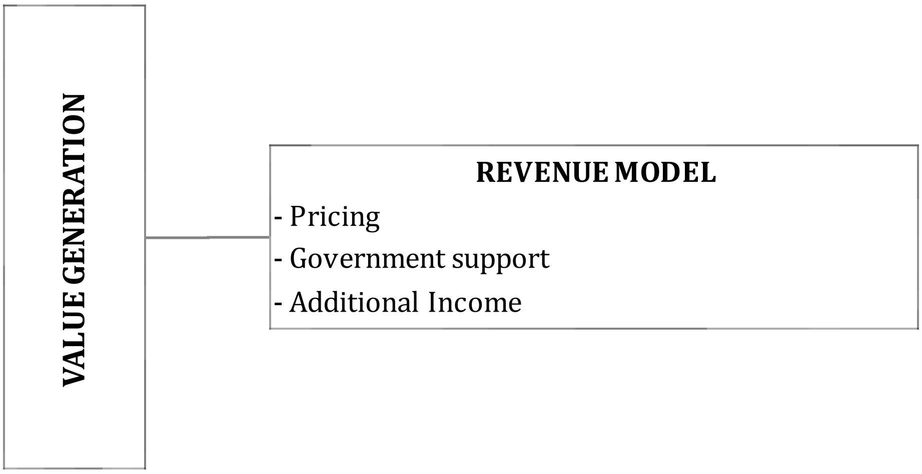
Source: Personal elaboration

We can consider the value chain configuration mentioned here under three subheadings: development & production, sales and end of the life policy. It includes different stakeholders in development and production content. At this point, autonomous ship manufacturers need to determine whether they will produce autonomous ships, which they should focus on in their production strategies, in-house or depending on external resources. As a result of the interviews made so far, there is a complexity in the production of autonomous ships and this is expected to be outsourced at least in some components. Another strategy that manufacturers should define in the development and production content of autonomous ships is to decide whether to adopt traditonal vessel or a mixed strategy by adding additions to traditional ships or from scratch, and to do both of these. The autonomous ships' sales technique have a plan that be a key challenge for manufacturers. So, they will able to sell autonomous ships from first hand to shipping companies, owners of the ship taken into account their requests or manufacturers can directly work with shipbrokers who specialized in sales and purchasing chartering. In fact, even though sales may seem like a difficult process, we can say that the real difficult process begins after the sale. At this point, the quality and improvement of the after-sales service come to important. When autonomous ships are navigating in the open sea or docking in port, they may need to be repaired and intervened immediately. Skilled employees should be transported on and off the vessel by helicopter for repair on the high seas. It may be possible to locate needed specialized employees for harbour maintenance at major or special ports. Some package services may be provided by autonomous ship producers to their clients. Moreover, given speedly of technical improvement, regular technological updating might be included as part of the after-sales support. Because of advanced technology, autonomous ships are more expensive than traditional vessels. However, based on the concept of resource efficiency, many autonomous ship technology solutions are likely to be re-used in new Autonomous ship construction or for other purposes. As a result, autonomous ship manufacturers may provide end-of-life policies that include agreements for valuation at return or demolition.

Unlike entrepreneurial companies, incumbent companies that integrate their business model into their existing business models can often be outsourced for production and development. Entrepreneurial companies may define the development and production done on behalf of their company with their own resources, that is, internally. The research, which has been seen in the autonomous ship companies interviewed so far, is usually done within the companies themselves, but data sharing and complementary parts of autonomous ships are supportive of each other, in whichever companies have been developed with better innovation. As understanding from the searches and the information obtained, it can be thought that entrepreneurial businesses may remake their production and create a rebuilt autonomous ship from scratch, as they do in their business models. However, it seems likely that incumbent businesses may integrate already existing ships into autonomous ships. Entrepreneurial companies should be able to provide service at sea and port sides in their sales policies because a ship managed with a shore control center should have service providers on both sides, but incumbent companies are likely to have a supporting team only at the port. In fully autonomous ships, a value return policy or demolition policy should definitely be provided when the life of the ship provided by entrepreneurial companies expires but providing demolition service on semi-autonomous ships as it is not on traditional ships may not seem like much logic.

3.4.3 Revenue Generation

Figure 16 . Value Generation of Autonomous ship's Business Model



Source: Personal elaboration

A revenue model is a framework for generating financial income. It determines which revenue source to pursue, what value to provide, how to price the value, and who pays for the value (Wikipedia, 2022). Depending on the service theme in the value proposition, autonomous ship producers may offer an autonomous ship for a fixed amount or charter ships for predefined voyage or time for set amount per voyage or per day. While autonomous ships provide economic, environmental, and social advantages, government are anticipated to give both financial and non-financial benefits to autonomous ship producers and other players in the autonomous ship manufacturing and growth value chain. These incentives will be incorporated into the revenue model since they will get lower the total cost of autonomous ship manufacture. Moreover, autonomous ship producers may create additional revenue by licencing their technology to others. So, a business model for an autonomous ship producing company may be created by integrating various activities from the these aspects which we mentioned on previous subheading of the autonomous ship business model. As we know, a excellent business model must have the potential to transform an industry's economics and also provide a significant competitive advantage. In this stage how can we know what the correct business model for autonomous ship producers? In most emerging sectors, companies first try to catch for a standard business model and when they found it, this business model is generally shared by several competitors.

If looking at the revenue model of business modelling in both types of businesses, we may identify pricing, government support and possible additional income. We can assume that pricing in incumbent and entrepreneurial businesses may also emerge from ship sales and in the case of ship chartering. However, in entrepreneurial companies, direct selling seems more logical if the product their target product is fully autonomous ships, and the production fees of fully autonomous ships are higher. We do not think that there may be government support for incumbent companies, as in traditional ships, but it can be predicted that the government support may be considerably higher, considering how much the new developing system and its contribution to the world's trade and environment will be considered in entrepreneurial companies. As incumbent companies will not have an additional income to modify their business models, as business modelling will be rebuilt in entrepreneurial companies, perhaps a technology-based licensing may be provided, as mentioned the previous parts.

Conclusion

The potential to remotely control autonomous vessels and utilize the opportunities provided by automation innovations has the potential to convert the way all kind of the vessels and on-board components are operated across the world. This technological shipping revolution may lead to the development of autonomous vessels. Unfortunately, autonomous vessels, like all other innovative products and technologies, encounter significant challenges that prevent potential advancements from growing in the trade shipping market businesses. It is critical to investigate these challenges in order to develop solutions to address or overcome them. In this context, in order to understand the main strength and weak points, opportunities and threats respect to business, legislation, and transport, four biggest autonomous shipping companies have been analysed as the first step to outline a proper autonomous shipping maritime business model. The study aimed to analyse opportunities and threats that autonomous vessels' bring and could bring to operating processes of global maritime businesses and the shipping industry, examining the digital transformation experienced on ships, investigate if autonomous vessels will be the solution to sea transportation under the light of their advantages and figuring out whether autonomous vessels are already falling under the same type of legal framework as traditional vessels. Moreover, to analyze the contributions and challenges that businesses and management activities must faced with autonomous vessels, four of the biggest autonomous maritime companies that already experiencing automation have been asked for support. The following answers emerged on the achievement of the general purpose of this research.

Based on the literature reviews and the outputs of the interviews, autonomous ships appear as the solution to sea transportation and logistics process. It is predicted that the Autonomous Ship will influence the logistics processes and maritime transportation. Now innovations that have already been tested, will result need.

It should have a positive effect on all logistic processes so, we can say that connecting autonomous shipping with autonomous systems onshore, such as cranes, trucks, will affect both their own structures and the ecosystem, which they are affected in a good way to ensure all necessary resources are available at the correct time to minimize waiting time. At the point where its importance is emphasized that autonomous shipping companies' seamless and emission free logistics is the driver for their projects and customers. Everything in the customers logistics chain needs to be automated, flexible, and efficient. The sector is able to identify autonomous ships that are already falling under the same type of international conventions as traditional ships and some modifications to legalization might be made for the autonomous ship to navigate on the high sea.

Autonomous ship manufacturers and complementary companies, which looked at the outputs from the scientific literature revealed that there is no problem in defining autonomous ships as ships. We concluded that having a master or crew on the ship does not appear to be important aspect of identifying a ship, hence most autonomous ships would be recognized by current legal definitions, and conventions and nationals law may continue to apply to them. After examining international conventions analysing the main international conventions and analysing the interviewed responses, the following conclusion was reached: it seems possible to affirm that there is no obstacle for autonomous ships to be qualified as a ship in terms of their legal nature within the scope of UNCLOS, and the relevant provisions examined in this study will not cause problems that cannot be overcome in general. Most of the provisions in MARPOL do not find applications for autonomous ships. From my perspective, main point to be considered here is that while describing the term ship in the MARPOL convention, there is no statement regarding the presence of the crew on the ship as a determining factor. For this reason, it seems possible to conclude autonomous ships will be considered as ships under the convention. Given that COLREGs regulate all or some unmanned surface and underwater vehicles, such vehicles must be developed to meet its requirements, operate safely, and also being visible to other craft. While operating in international waters, unmanned surface vehicles and unmanned underwater vehicles that operate autonomously or under the command of a controller must be programmed to comply with such legislation. The mentioned SOLAS's articles should be evaluated and revised for unmanned ships. As a result of this revision, if these responsibilities can be intervened from the shore control center, then according to the SOLAS convention, the ships may become unmanned, and this may not result in any bad results. The STCW regulates the minimum training and qualification standard for seafarers serving on seagoing vessels. On the other hand, it is an undeniable fact that there will be different training and qualification standards for the shore-based personnel to be assigned to autonomous ships due to the nature of the work they undertake. Therefore, it seems that, besides the fact that the current provisions of the STCW do not seem likely to be applied to the persons involved in autonomous ship operations, making changes in the relevant convention in this direction would be a more reasonable solution than issuing a new international convention corresponding to the STCW contract to be applied exclusively to autonomous ships.

Autonomous ships create opportunities such as reduce human incidents, errors and maritime accidents, more effective use of vessel's hull space so increase the cargo capacity, energy effective operations of ships, cheaper to transport the goods, more safety, reduce the fuel, more effectively control fuel consumption, lower operational cost, optimized and repetitive time management, reduce pirate attacks, solution to pandemic scenario, and requiring trained specialists that make new job opportunities arise. Complications to autonomous ships are threats such as require huge technological investment, development of ground operations to control fleet operations, shortage of staff on the high sea to take control immediately, extremely strong monitoring and control even in extreme weather conditions, people who work on the sea and shore potentially loss their job, re-modified ship management system, no guarantee of more greener and safer waters, safety and security difficulties for vessels in conflict zones, public opinion after an accident, remote control risk and cyber-attacks, legal implications of marine regulations, uncertainty of maritime insurance, and energy supply risk from the company perspectives.

After concluded the literature and analysed interview answers we can mention that the maritime business model is possible applied and integrated into autonomous ships. At this point, it is important to focus on the exactly key components. Based on the main key aspect of this research we are able to suppose a business model by defining target segment and identifying how production expands. As with most technologies, there are niches which are more attractive than others when it comes to finding profitable solutions. The first movers are currently not seeing lower investment costs and the profit model is also still uncertain. But in the long run, this will be more evident and pronounced. But still, there will be segments within the shipping industry which might not benefit largely from this in the near future. Autonomous shipping companies and maritime industry major players can develop new constitutive strategies maximizing strengths and minimization of weaknesses. In this perspective, , the opportunities and threats resulted by the analysis could represent a starting point to consider defining new maritime business model based on autonomous ship use.

Beyond the specific business model, the digitalization of maritime industry onboard and shore sides is going to be gradual and incremental since it represents crucial feature to allows Autonomous Shipping implementation. Along that evolutionary process, the training function of company plays a key role in support the changes. It is concluded that the future of the sea transportation sector is significantly reliant on autonomous shipping, which has great potential if the difficulties are effectively addressed. From a broader perspective, AS provides a wider field of investigation. Due to all the implications, it has on the companies, traders, to mention but a few, AS provides a wider field of investigation, influencing the multiple aspects of sea transportation.

REFERENCES

Dr. Eric Van Hooydonk, 2014. *The law of unmanned merchant shipping – an exploration,* s.l.: Advocate at the Antwerp Bar, Research Professor at the University of Ghent.

Abdulrahim, H., 1994. *Maritime Carrier's Liability for Loss of or Damage to Goods under Hague Rules, Visby Rules and Hamburg Rules, compared with his Liability as an Operator under the Relevant Rules of the International Multimodal Transport Convention,* Glasgow: s.n.

Akçakaya, H. Y. H. A. S. G. a. F. G., 2009 . *Sliding Mode Control of an Autonomous Underwater Vehicle.* Bursa Turkey, International Conference on Electrical Engineering Eleco 2009.

Alfredo ALAN Flores., J. H. A. C. G. Y. L., 2017. Energy-Efficient Through-Life Smart Design, Manufacturing and Operation of Ships in an Industry 4.0 Environment. April, p. 4.

AMOS, 2015. *Centre for Autonomous Marine Annual Report,* Trondheim: Norwegian University of Science and Technology.

An E, Dhanak M, Shay LK, Smith S, 2001. *Coastal oceanography using a small AUV,* s.l.: Atmospheric and Oceanic Technology.

Ang, J. G. C. L. Y., 2016. *Smart design for ships in a smart product through-life and industry 4.0 environment.* s.l., IEEE Congress on Evolutionary Computation, CEC 2016.

Anon., 2014. *Electronics Maker, Unmanned Vehicles—No pilot/driver on Board.* s.l.:s.n.

Antonelli, G., 2006. *Underwater Robots: Motion and Force Control of Vehicle-Manipulator Systems.* s.l.:s.n.

Aphornsuvan, T., 2016. Strengthen the Rule of Law in the Regions on International Law on the Sea. *Thammasat University Journal.*

Arkajyoti Mukherjee, 2021. *The Impact of Autonomous Shipping: Maritime Jobs, Pollution,Safety and More.* [Online]
Available at: https://marinemonks.com/impact-of-autonomous-shipping-maritime-jobs-pollution-safety/ [Accessed 22 January 22].

Autonomous Boats & Unmanned Surface Vessels for Marine Monitoring, H. S. &. R., 2021.*Unmanned Systems Technology.* [Online]
Available at: https://www.unmannedsystemstechnology.com/company/oceanalpha/
[Accessed 2021].

Autonomous Ships Global Market Report 2021, 2021. *Research and Markets.* [Online] Available at: https://www.researchandmarkets.com/reports/5321502/autonomous-ships-global-market-report-2021-covid?utm_source=GNOM&utm_medium=PressRelease&utm_code=6vpq8g&utm_campaign=1546580+-+Global+Autonomous+Ships+Market+Report+2021-2030%3a+Increasing+Threat+of+Cybe
[Accessed 22 May 2022].

Autonomous Ships HQ, 2022. *Autonomous Ships HQ.* [Online]
Available at: https://www.autonomousshipshq.com/revolt/#prettyPhoto
[Accessed 16 February 2022].

Baibhav, M., 2020. *seanews.* [Online]
Available at: https://www.seanews.co.uk/shipping-news/artificial-intelligence-and-the-era-of-autonomous-shipping/
[Accessed 20 05 2022].

Baldauf, M., 2018. *E-navigation, digitalization and unmanned ships: challenges for future maritime education and training..* s.l.:s.n.

Berlingieri, F., 2009. *The History of Rotterdam Rules,* s.l.: s.n.

Blanke, M. K. P. L. a. T. I. F., 2000. *Dynamic Model for Thrust Generation of Marine Propellers,* Aalborg, Denmark: Proc. 5th IFAC Conference of Maneuvering and Control of Marine Craft (MCMC'00).

Brendan P. Sullivan, E. A. N. S. D. J. S. M. R. L. R. S. T., 2020. *Defining Maritime 4.0: Reconciling principles, elements and characteristics to support maritime vessel digitalisation,* s.l.: IET Collaborative Intelligent Manufacturing.

Brendan P. Sullivan, E. A. N. S. D. J. S. M. R. L. R. T., 2021. *"Defining Maritime 4.0: Reconciling principles,elements and characteristics to support maritime vessel digitalisation",* s.l.: IET Collaborative Intelligent Manufacturing.

Caputo, A., 2018. *STCW Electronic Edition,* s.l.: s.n.

Cebollero, A. S. L., 2017. *Virtual reality empowered design.* s.l., s.n.

Christina Vossen, R. K. R. H., 2013. *Ship Design and System Integration.* s.l., s.n.

Cicek, K. A. E. C., 2019. *Future skills requirements analysis in maritime industry,* s.l.: Procedia Comput. Sci.

CMI, 2021. *Maritime Law for MASS.* [Online] Available at: https://comitemaritime.org/work/mass/ [Accessed 10 March 2022].

CMI, 2021. *Position Paper on Unmanned Ships.* [Online]Available at: https://comitemaritime.org/work/mass/ [Accessed 11 March 2022].

CMI, 2021. *Summary of Responses to the CMI Questionnaire.* [Online]Available at: https://comitemaritime.org/work/mass/ [Accessed 11 March 2022].

CMI, 2022. *The Work of the CMI: International Working Groups (Past and Present) Maritime Law for Maritime Autonomous Surface Ships (MASS).* [Online]Available at: https://comitemaritime.org/recent-work/ [Accessed 11 March 2022].

COLREGs, 1960-1977. *Convention on the International Regulations for Preventing Collisions at Sea and International Regulations for Preventing Collisions at Sea.* s.l.:s.n.

Commission, E., 2019. *Autonomous Shipping Initiative for European Waters.* [Online]Available at: https://trimis.ec.europa.eu/project/autonomous-shipping-initiative-european-waters#tab-outline [Accessed 2021].

Committee, M. S., 2018. *REGULATORY SCOPING EXERCISE FOR THE USE OF MARITIME AUTONOMOUS SURFACE SHIPS (MASS),* Norway: IMO.

Çetin, Prof. Dr. Oktay, 2018. *Marine Culture,* Istanbul: MarineDeal.

Daum, O., 2018. *The Implications of International Law on Unmanned Naval Craft", Journal of Maritime Law& Commerce,* s.l.: s.n.

DNV, 2021. *DNV.* [Online]
Available at: https://www.dnv.com/maritime/autonomous-remotely-operated-ships/index.html [Accessed 2021].

DNV, 2022. *DNV.* [Online]
Available at: https://www.dnv.com/about/index.html [Accessed 15 05 2022].

DW News, 2021. *Suez Canal: Ship blockage may be due to 'human errors'.* [Online]Available at: https://www.dw.com/en/suez-canal-ship-blockage-may-be-due-to-human-errors/a-57022549[Accessed 2022].

Ece, Dr. Jale Nur, 2006. Dünya Deniz Ticareti ve Konteyner Taşımacılığı. *Kaptan Haber*, 5 haziran.

Edgar Gold, 1981. *Maritima Transport: The Evolution of Internatıonal Marine Policy and Shippin Law,* s.l.: s.n.

Ela Bulut, D. D. T. A., 2017. ENDÜSTRİ 4.0 VE İNOVASYON GÖSTERGELERİ. *ASSAM Uluslararası Hakemli Dergi (ASSAM - UHAD) ASSAM International Refereed Journal,* Volume 7, pp. 50-51.

Ellingsen, O. K., December 2019. *Digitalizing the Maritime Industry: A Case Study of Technology Acquisition and Enabling Advanced Manufacturing Technology,* s.l.: s.n.

Eloranta, S., 2019. *Autonomous Ships. Automated maritime transport: why, how and when,* s.l.: Head of Innovation & Technology Rolls-Royce.

Executive, M., 2021. *An Early Look at ASKO's Autonomous Freight Ferries.* [Online]Available at: https://www.maritime-executive.com/article/an-early-look-at-asko-s-autonomous-freight-ferry [Accessed 2021].

FinFerries, 2020. *Annual Report and Corporate Responsibility Report,* s.l.: Suomen Lauttaliikenne Group.

Fisheris, N., 2020. *Autonomous Vehicles Help Scientists Estimate Fish Abundance While Protecting Human Health and Safety.* [Online]
Available at: https://www.fisheries.noaa.gov/feature-story/autonomous-vehicles-help-scientists-estimate-fish-abundance-while-protecting-human [Accessed 2021].

Gandolfi, E., 2018. *Virtual Reality and Augmented Reality.* Handbook of Research on K-12 Online and Blended Learning (2nd ed.) ed. s.l.:s.n.

Gaspar, H. M., 2018. *Data-Driven Ship Design.* Italy, s.n.

Gautam Saxena, 2021. *NYK And Orca AI To Jointly Work For New Safety Support Systems For Autonomous Vessels.* [Online]
Available at: https://marinemonks.com/nyk-and-orca-ai-to-jointly-work-for-new-safety-support-systems-for-autonomous-vessels/ [Accessed 2022].

Ginters, E. P. V. R. E. M., 2019. *ICTE in Transportation and Logistics,* s.l.: vol. 149. Springer.Guibert, C. E. F. N. A.-A. a. L. L., 2005. *Thrust control of electric marine thrusters,* Raleigh, North Carolina, USA: Proc. 32nd Annual Conf. IEEE Industrial Electronics Society (IECON2005).

Guidi, A., 2021. The Watchwords: Technology and Smart Ports. *ISPI (Italian Institute for International Political Studies)*, 29 March .

H/HVR, 1968. *The Hague/The Hague-Visby Rules,* s.l.: s.n.

HAGGER, B. G. A. M., 2008. *The Laws of Man over Vehicles Unmanned: The Legal Response to Robotic Revolutionon Sea, Land and Air,* s.l.: s.n.

Helen Tung, R. V. M. T. A. S., 2016. *Liability for operations in Unmanned Maritime Vehicles with Differing Levels of Autonomy Deliverable,* s.l.: s.n.

Hooydonk, P. D. E. V., 2014. *The law of unmanned merchant shipping – an exploration,* Belgium: Advocate at the Antwerp Bar, Research Professor at the University of Ghent.

Housel, T. J. M. F. N. H., 2015. *Benchmarking Naval Shipbuilding with 3D Laser Scanning, Additive Manufacturing, and Collaborative Product Lifecycle Management,* Naval Postgraduate School Monterey United States: s.n.

Hull, H. t., 2017. *Using EGNOS and Galileo to support Autonomous Maritime Operations.* [Online] Available at: https://www.sintef.no/projectweb/hull-to-hull/ [Accessed 20 January 2022].

ICS(International Chamber of Shipping), 2018. *Press release. "Separating Fact from Fiction: ICS Releases New Study on Seafarers and Digitalization.".* [Online]Available at: https://www.ics-shipping.org/press-release/separating-fact-from-fiction-ics-releases-new-study-on-seafarers-and-digitalisation/ [Accessed 20 May 2022].

IMO, 2018. *IMO takes first steps to address autonomous ships.* [Online] Available at: https://www.imo.org/en/MediaCentre/PressBriefings/Pages/08-MSC-99-MASS-scoping.aspx [Accessed 22 January 2022].

IMO, 2021. *OUTCOME OF THE REGULATORY SCOPING EXERCISE FOR THE USE OF MARITIME AUTONOMOUS SURFACE SHIPS (MASS),* LONDON: IMO.

IMO, 2022. *INTERNATIONAL MARITIME ORGANIZATION.* [Online]
Available at: https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx [Accessed 14 MARCH 2022].

Insight, M., 2018. *Rolls-Royce And Finferries Demonstrate World's First Fully Autonomous Ferry.* [Online] Available at: https://www.marineinsight.com/shipping-news/rolls-royce-and-finferries-demonstrate-worlds-first-fully-autonomous-ferry/ [Accessed 2021].

Işın KURT, Mehmet Bilge Kağan ÖNAÇAN;, 2018. *Endüstri 4.0 Kavramı ve Kattığı Değerlerin Silahlı KuvvetlerdeGünümüzde ve Gelecekte Kullanım Alanları.* Ankara, s.n.

Iwakami H., U. T. A. K. H. T. N. Y. K. J. S. Y. A. T. U. S., 2021. *Approaching whales by autonomous underwater vehicle,* s.l.: Journal of Marine Technology Society.

Jorge, V., 2019. *A Survey on Unmanned Surface Vehicles for Disaster Robotics: Main Challenges and Directions,* s.l.: s.n.

Karan, H., 2004. *The carrier's Liability Under International Maritime Conventions The Hague, Hague-Visby, and Hamburg Rules,* New York: s.n.

Kim, J. a. W. K. C., 2006. *Accurate and Practical Thruster Modeling for Underwater Vehicles. Ocean Engineering,* s.l.: s.n.

Klesty, V., 2021. *world's first autonomous electric container ship.* Norway: s.n.

KONGSBERG MARITIME, 2018. *WILHELMSEN AND KONGSBERG ESTABLISH WORLD'S FIRST AUTONOMOUS SHIPPING COMPANY.* [Online]
Available at: https://www.kongsberg.com/maritime/about-us/news-and-media/news-archive/2018/wilhelmsen-and-kongsberg-establish-worlds-first-autonomous-shipping-company?OpenDocument [Accessed 20 January 2022].

Kongsberg, 2021. *Kongsberg.* [Online]
Available at: https://www.kongsberg.com/maritime/ [Accessed 30 January 2022].

Koren, Y. S. M., 2010. *Design of Reconfigurable Manufacturing Systems,* s.l.: 4. Elsevier Ltd.

Kostidi, E. N. N., 2017. *Exploring the potential of 3D printing of the spare parts supply chain in the maritime industry.* s.l., Safety of Sea Transportation: Proceedings of the 12th International Conference on Marine Navigation and Safety of Sea Transportation, p. 171–178.

Koustav, D., 2021. *Explained: How much did Suez Canal blockage cost world trade.* [Online]
Available at: https://www.indiatoday.in/business/story/explained-how-much-did-suez-canal-blockage-cost-world-trade-1785062-2021-03-30 [Accessed 16 05 2022].

Kroll, K., 2021. *Maritime Logistics: Water Ya Gonna Do?,* s.l.: Hapag-Lloyd Goes LNG.

Leo McLeman, M. C. F. L. C. D. C., 2021. *Five future trends in the shipping industry.* [Online] Available at: https://www.marine-i.co.uk/news/article/4/five-future-trends-in-the-shipping-industry [Accessed 2021].

Lindegaard, K.-P. a. T. I. F., 2003. *Fuel Efficient Rudder and Propeller Control Allocation for Marine Craft: Experiments with a Model Ship.* s.l.:IEEE Transactions on Control Systems Technology 11(6).

LINE, N., 2019. *NYK Conducts World's First Maritime Autonomous Surface Ships Trial.* [Online] Available at: https://www.nyk.com/english/news/2019/20190930_01.html [Accessed 2021].

Li, Y., 2006. *CAutoCSD-evolutionary search and optimisation enabled computer automated control system design.* s.l.:s.n.

Lloyd's Register, 2009. *Lloyd's Register Rulefinder 2005 – Version 9.4. COLREGS - International Regulations for Preventing Collisions at Sea.,* s.l.: s.n.

M. Schiaretti., L. C. R. N., 2017. *Survey on autonomous surface vessels: Part i - a new detailed definition of autonomy levels.* Southampton, UK, 8th International Conference on Computational Logistics.

Machines, S., 2020. *Unmanned Hydrographic Survey Operations for Higher Quality Data Collection & Increased Safety.* [Online]
Available at: https://sea-machines.com/unmanned-hydrographic-survey-operations-for-higher-quality-data-collection-increased-safety#deepanch [Accessed 2021].

MahmoudZadeh, S., 2017. *Autonomous Reactive Mission Scheduling and Task-Path Planning Architecture for Autonomous Underwater Vehicle.* [Online]
Available at: https://theses.flinders.edu.au/view/a3bffa9b-38e0-4252-9c57-c42ef7d4a7d5/1 [Accessed 2021].

Marine Digital, 2021. *Marine Digital.* [Online] Available at: https://marine-digital.com/article_robotics_in_maritime_industry [Accessed 11 December 2021].

Marine Insight, 2018. *DNV GL Releases Autonomous And Remotely Operated Ship Guideline* [Online] Available at: https://www.marineinsight.com/shipping-news/dnv-gl-releases-autonomous-and-remotely-operated-ship guideline/?fbclid=IwAR2tCVG0gyt5EXocGArpYZ6IShkUr8NZREGrCypNOoLzqYlegN9vU NukTw [Accessed 22 January 2022].

Marinemonks News Network, 2021. *Marinemonks.* [Online] Available at: https://marinemonks.com/av-zhi-fei-chinas-first-autonomous-containership-set-to-enter-service/ [Accessed 20 January 2022].

MARITIME SAFETY COMMITTEE, 2018. *REGULATORY SCOPING EXERCISE FOR THE USE OF MARITIME AUTONOMOUS SURFACE SHIPS (MASS),* s.l.: IMO.

Mark W. Johnson, J. S., 2009. *How to Jump-Start the Clean Economy.* s.l.:Harvard Business Review.

Martimo, P., 2017. *DISRUPTIVE INNOVATION AND MARITIME SECTOR.* Turku: Turku School of Economics.

Massterly, 2020. *A SNAPSHOT OF SOME OF THE PROJECTS WE ARE INVOLVED IN.* [Online] Available at: https://www.massterly.com/news-1 [Accessed 2021].

Massterly, 2022. *Massterly.* [Online] Available at: https://www.massterly.com/what-we-do [Accessed 24 May 2022].

Matter, t. P. t. t. C. o. t. P. o. M. P. b. D. o. W. a. O., 1996. *Article III.* London: s.n.

Maxwell, H., 2018. *Autonomous ships,* s.l.: Technology Bulletin.

Mitsui O.S.K. Lines, 2017. *MOL Launches R & D on Autonomous Ocean Transport System.* [Online] Available at: https://www.mol.co.jp/en/pr/2017/17031.html [Accessed 30 January 2022].

Mitsui O.S.K. Lines, 2022. *Mitsui O.S.K. Lines.* [Online]
Available at: https://www.mol.co.jp/en/pr/2022/22007.html [Accessed 14 5 2022].

Molland, A., 2008. *The Maritime Engineering Reference Book.* 1st Edition ed. s.l.:s.n.

Monica Rossi, B. P. S. S. D. J. S. L. R. S. T., 2019. *Maritime 4.0 – Opportunities in Digitalization and Advanced Manufacturing for Vessel Development.* Austria, s.n.

MUNIN, 2019. “Research in maritime autonomous systems project Results and technology potentials.”. *Maritime Unmanned Navigation through intelligence in networks.*

MUNIN, 2021. *Maritime Unmanned Navigation Through Intelligence in Networks.* [Online] Available at: http://www.unmanned-ship.org/munin/news-information/downloads-information-material/munin-deliverables/ [Accessed 30 january 2022].

MÜSİAD, 2018. *Report of Logistic Sector - Industry 4.0 and Logistic of Future,* Ankara: s.n.

Narayanan, A., Rajeshirke, P. & Sharma, A., 2019. *Pestonjamasp, K. Survey of the emerging bio-inspired Unmanned Aerial Underwater Vehicles..* Mumbai, India, In Proceedings of the 2nd International Conference on Emerging trends in Manufacturing, Engines and Modelling (ICEMEM -2019).

National Institute of Standards and Technology Special Publication, 2020. *Autonomy Levels for Unmanned Systems (ALFUS) Framework.* s.l.:s.n.

News, M. a. C., 2012. *Monster and Critics News website.* [Online] Available at: http://www.monstersandcritics.com/news/usa/features/article_1570512.php/In-Pictures-Gulf-Oil-Spill-BP-s-ROV [Accessed 2021].

Newspaper, G., 1990. *Denizlerin Gemiler Tarafından Kirletilmesinin Önlenmesine Ait Uluslararası Sözleşme.* s.l.:s.n.

Nikaki, T., 2010. The Carrier's Duties Under the Rotterdam Rules: Better the Devil You Know?. *Tulane Maritime Law Journal,* pp. 1-44.

Nikki Funke, M. C. R. M. K. N., 2014. *Reflections on the State of Research and Technology in South Africa's Marine and Maritime Sectors.* Pretoria, South Africa: s.n.

O'Brien, C., September 2018. *Autonomous ships,* s.l.: Technology Bulletin.

Oneto, L., 2016. *Vessel monitoring and design in industry 4.0: A data driven perspective.* s.l., IEEE 2nd international forum, pp. 1-6.

Opensea.PRO, 2021. *Autonomous Ships and their Impact.* s.l.:s.n.

Oxford Lib Guides, 2022. *International Convention for the Unification of Certain Rules of Law relating to Bills of Lading ("Hague Rules"),* s.l.: s.n.

Pakkanen, P. H. E., 2016. *How data is shaping the future of vessel design, navigation and operation.* s.l., RINA Smart Ship Technology.

Perry, C., 2005. *Education for digitization: how do we prepare?.* s.l.:J. Acad Librariansh.

Petersen, J. K., 2009. *Understanding Surveillance Technologies.* Second Edition ed. s.l.:s.n.

Publication, N. I. o. S. a. T. S., 2020. *Autonomy Levels for Unmanned Systems (ALFUS) Framework.* s.l.:s.n.

Raptodimos, Y., 2016. *Ship sensors data collection & analysis for condition monitoring of ship structures & machinery systems,* s.l.: s.n.

Research and Markets, 2021. *Globe Newswire.* [Online]
Available at: https://www.globenewswire.com/news-release/2021/06/08/2243287/28124/en/Global-Autonomous-Ships-Market-Report-2021-2030-Increasing-Threat-of-Cybersecurity-and-Privacy-is-Expected-to-Limit-Market-Growth.html#:~:text=and%20Praxis%20Automation%20Technology%20
[Accessed 22 May 2022].

Researhes Briefs, 2018. *Massive Cargo Ships Are Going Autonomous. Here Are The Companies & Trends Driving The Global Maritime Industry Forward.* [Online]Available at: https://www.cbinsights.com/research/autonomous-shipping-trends/
[Accessed 15 05 2022].

Rivas, Á. R., 2018. *Navantia's Shipyard 4.0 model overview,* s.l.: s.n.

Riviera, 2020. *Samsung tests autonomous ship technology on tug.* [Online]Available at: https://www.rivieramm.com/news-content-hub/news-content-hub/samsung-tests-autonomous-ship-technology-on-tug-61383
[Accessed 2021].

Robert Veal, M. T. A. S., 2019. *The legal status and operation of unmanned maritime vehicles,* s.l.: s.n.

Roberts G., S. R., 2006. *Advances in Unmanned Marine Vehicles.* london: s.n.

Roberts, 2019. *Timeline – Development of Autonomous Ships (1970s – 2018).* [Online] Available at: http://infomaritime.eu/index.php/2018/06/08/timeline-development-of-autonomous-ships/#:~:text=The%20concept%20of%20autonomous%20ships,with%20the%20use%20of%20computers. [Accessed January 2021].

Rodič, B., 2017. *Industry 4.0 and the new simulation modelling paradigm,* Slovenia: s.n.

Rolls-Royce, 2018. *Rolls-Royce and AXA to jointly develop risk management products for autonomous shipping.* [Online]

Available at: https://www.rolls-royce.com/media/press-releases.aspx#14-05-2018-rr-and-axa-to-jointly-develop-risk-management-products-for-autonomous-shipping [Accessed 22 January 2022].

Rolls-Royce, 2018. *Rolls-Royce and Finferries demonstrate world's first Fully Autonomous Ferry.* [Online]
Available at: https://www.rolls-royce.com/media/press-releases/2018/03-12-2018-rr-and-finferries-demonstrate-worlds-first-fully-autonomous-ferry.aspx [Accessed 2021].

Rolls-Royce, 2021. *Rolls-Royce demonstrates world's first remotely operated commercial vessel.* [Online]
Available at: https://www.rolls-royce.com/media/press-releases/2017/20-06-2017-rr-demonstrates-worlds-first-remotely-operated-commercial-vessel.aspx [Accessed 30 January 2022].

Rothblum, D. A. M., 2022. *Human Error and Marine Safety.* s.l.:s.n.

Rozas, O. d., 2014. *The production of unmanned vessels and its legal implications in the maritime industry,* Oslo: University of Oslo.

S Rosenne., N. R. G. S. N. N., 1982. *United Nations Convention on the Law of the Sea,* s.l.: s.n.

Salvage, I. I. C. O., 1997. *LexMercatoria.org.* [Online]
Available at: https://www.fd.unl.pt/docentes_docs/ma/wks_MA_31688.pdf [Accessed 20 February 2022].

Saxon, S. &. S. M., 2017. *Container shipping: the next 50 years..* s.l.:Whitepaper McKinsey.

Sea, U. N. D. f. O. A. a. t. L. o. t., 2022. *Chronological Lists of Ratifications of, Accessions and Successions to the Convention and the Related Agreements.* [Online]
Available at:
https://www.un.org/depts/los/reference_files/chronological_lists_of_ratifications.htm [Accessed 10 March 2022].

SHM, 2018. *Safe Seas, Safe Shores.* [Online]
Available at: https://www.shmgroup.com/blog/everything-need-know-port-automation/ [Accessed 11 December 2021].

SOLAS, 1974. s.l.: s.n.

Somaiyeh MahmoudZadeh, D. M. P. R. B. Z., 2018. *Autonomy and Unmanned Vehicles - "Augmented Reactive Mission–Motion Planning.* Australia: s.n.

SPURV, 2021. *Special Purpose Underwater Research Vehicle (SPURV).* [Online] Available at: http://www.navaldrones.com/ [Accessed December 2021].

Stanić, V., 2018. *Toward shipbuilding 4.0-an industry 4.0 changing the face of the shipbuilding industry.* s.l.:Brodogradnja.

Status: United Nations Convention on the Carriage of Goods by Sea (Hamburg, 1. (. ". R., 1978. *United Nations Commission On International Trade Law.* [Online] Available at: https://uncitral.un.org/en/texts/transportgoods/conventions/hamburg_rules/status [Accessed 4 March 2022].

STCW, 1978. s.l.: s.n.

Stietencron, v., 2017. *Applying closed-loop product lifecycle management to enable fact based design of boats,* s.l.: s.n.

Sullivan, B., 2018. *Integrated solution supporting the design of specialized connected vessels.* XXIII Summer School "Francesco Turco" – Industrial Systems Engineering ed. LINCOLN: s.n.

Sullivan, B., 2019. *A prospective data-oriented framework for new vessel design.* s.l., IEEE International Conference on Engineering Technology and Innovation, p. 1–8.

Summary, F. R., 2016. *MUNIN (Maritime Unmanned Navigation through Intelligence in Networks).* [Online] Available at: https://cordis.europa.eu/project/id/314286/reporting [Accessed 2021].

Tauss Marine, 2017. *Denizde Can Emniyeti Uluslararası Sözleşmesi (Safety Of Life At Sea – SOLAS),* s.l.: s.n.

Tetley, W., 2002. *International maritime and admiralty law.* Quebec : s.n.

The Maritime Executive, 2018. *Japan Prepares for Autonomous Tugboat Test.* [Online] Available at: https://maritime-executive.com/article/japan-prepares-for-autonomous-tugboat-test?fbclid=IwAR0delCNzMDTOwBlsXjTJtoIzIcBYbr751_qPpyzqWdxcFKogpZOUHA2GEo [Accessed 22 January 2022].

The Medi Telegraph, 2019. *The Medi Telegraph.* [Online]
Available at:
https://www.themeditelegraph.com/en/shipping/2019/05/22/news/ship-aims-to-be-first-to-cross-atlantic-without-a-crew-1.38069866 [Accessed 12 January 2022].

TheNavalArch, 2019. *Autonomous ships of the future,* s.l.: s.n.

Thortech, 2017. *A Brief History of Maritime Shipping.* [Online]Available at: https://www.thortechnology.co.uk/ships/a-brief-history-of-maritime-shipping/
[Accessed 10 10 2021].

Tom van Dijk, H. M. v. D. N. v. d. B., 2019. *Smart ships and the changing maritime ecosystem,* Netherlands: Smart Port.

Trivyza, N. R. A. T. G., 2016. *The influence of ship operational profile in the sustainability of ship energy systems..* s.l., International Conference of Maritime Safety and Operations.

Tvete, H. A., 2015. *UNMANNED VESSELS – THE DNV GL "REVOLT" PROJECT,* s.l.: DNV GL .

Tvete, H. A., n.d. *DNV.* [Online]
Available at: https://www.dnv.com/technology-innovation/revolt/ [Accessed 2021].

UNCITRAL, 2022. *Overview of the Status of UNCITRAL Conventions and Model Laws.*
[Online]
Available at: <https://uncitral.un.org/sites/uncitral.un.org/files/media-documents/uncitral/en/overview-statustable. [Accessed 4 March 2022].

UNCLOS, 1982. *United Nations Convention on Law of the Sea.* s.l.:s.n.

UNCTAD, 2020. International maritime trade under severe pressure. *REVIEW OF MARITIME TRANSPORT 2020*, DECEMBER, p. 11.

UNCTAD, U. N. C. O. T. A. D., 2019. *REVIEW OF MARITIME TRANSPORT,* Geneva: United Nations.

UNCTAD, U. N. C. o. T. a. D., 2020. *Review of Maritime Transport,* Geneva: United Nations Publications.

Van Cappelle, L. C. L. &. N. R., 2018. *Survey on ASV technology developments and readiness levels for autonomous shipping. In Proceedings of the 9th International Conference on Computational Logistics.* Vietri sul Mare, Italy, s.n.

Veal, R. a. T. M., 2017. *The integration of unmanned ships into the lex maritima.* Lloyd's Maritime & Commercial Law Quarterly,2017 ed. s.l.:s.n.

Voytenko, M., 2020. *Coronavirus already hitting shipping, hard.* [Online]Available at: https://www.fleetmon.com/maritime-news/2020/28805/coronavirus-already-hitting-shipping-hard/

Walker, J., 2019. *Autonomous Ships Timeline – Comparing Rolls-Royce, Kongsberg, Yara and More.* Norway: s.n.

Wikipedia, t. f. e., 2022. *Wikipedia.* [Online]
Available at:
https://en.wikipedia.org/wiki/Revenue_model#:~:text=A%20revenue%20model%20is%20a,of%20a%20company's%20business%20model. [Accessed 03 06 2022].

Williams SB, Pizarro O, Jakuba M, Barrett N, 2010. *AUV benthic habitat mapping in South Eastern Tasmania.* s.l., 7th International Conference of Field and Service Robotics, pp. 275-284.

Wilson, J., 2010. *Carriage of Goods by sea,* London: s.n.

Wingrove, M., 2020. *Riviera-China will lead US$1.5Bn autonomous shipping market by 2025.* [Online]
Available at: https://www.rivieramm.com/news-content-hub/news-content-hub/china-will-lead-us15bn-autonomous-shipping-market-by-2025-58960 [Accessed 2021].

Witman S, 2017. *Detecting gas leaks with autonomous underwater vehicles.* s.l.:Journal of Geophysical Research: Oceans.

WorkBoat staff, 2021. *Autonomous ship market value to $165 billion by 2030, report says.* [Online]
Available at: https://www.workboat.com/autonomous-ship-market-value-to-165-billion-by-2030-report-says [Accessed 26 May 2022].

Yoon, P., 2017. *Maritime Epress.* [Online]
Available at: http://www.maritimepress.co.kr/news/articleView.html?idxno=203337
[Accessed 21 January 2022].

APPENDIX

1. What is your job position in the company?
2. I know that you have autonomous ship projects and some of these projects have been implemented. What was your/company purpose in actualizing an autonomous ship?
3. Could you identify the main Strengths, Weakness, Opportunity, and Threats about autonomous ships?

LOGISTICS AND BUSINESS MODEL

4. Do you think autonomous shipping could lead to a better logistic process? In which way?
5. In the last stage of my thesis, I will draft a maritime future business model in the light of the findings of my research and the interviews I have had with you, so I want to know how you evaluate the three main topics in the business model about autonomous ships:
    a. Value proposition
    b. Value chain configuration
    c. Profit/ Revenue Model

LABOUR LEGISLATION

6. As we know, in maritime law and international conventions, for a ship to be accepted within the framework of law, it must first be defined as a ship. Do you think autonomous ships can regarded as ships?
    a. What are your opinions on who will be the responsible party in case of any conflict? Is the cargo owner, Charterer, shipowner willing to take this risk?

b. In traditional ships, the responsible party is primarily the captain, but there will not be a captain here. It will be managed by Shore center control. If you are thinking Shore center control, will a ship always be controlled by the same SCC personnel?

TECHNOLOGICAL ASPECTS

7. While autonomous ships are being built, is it based on current ports or is it adapted for future smart ports? If it is adapted to the current port system, then what kind of system is followed during the loading and handling of the ship?
8. Is it possible to implement these autonomous technologies on all types of ships? If yes, for which ones it could be more effective and why? If no, for which ones it could be advisable and why?
9. Considering the Strengths, weakness, opportunity, and Threat about autonomous ships respect to logistic process, value chain and revenue model, the framework of law, do you think that autonomous ships will become widespread in the future and can completely replace traditional ships?