Feasibility Study of Autonomous and Remote-Controlled Vessels

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Abstract

This thesis is written on behalf of the company Foreship Ltd. Foreship's speciality is ship design and engineering. There are multiple purposes for this thesis. The first is to find out what degree of autonomous technology exists in vessels today and if there is a need for autonomous vessels. The second is to find out what is needed for autonomous technology to be implemented and what the future could look like. The third is to assess the best possible business opportunity for Foreship regarding autonomous and remote-controlled vessels.

The thesis consists of three main segments. The first segment is the theory which includes the theoretical aspects and background information regarding the implementations of autonomous technology. The current state of autonomy in vessels, what the future of autonomous vessels could look like, legal issues, safety issues and technological issues are important aspects in this segment. The second segment is the interviews. Qualitative interviews were conducted with experts working in different areas of the maritime industry. The purpose for this is to get different perspectives on the matter.

The third segment is the result and conclusion. The result contains a conclusion of the theory and interview segments as well as a business opportunity proposition for Foreship. The conclusion shows that there is a need for autonomous technology but there are several obstacles to overcome.

Language: English

Key words: autonomous, remote-controlled, MASS

EXAMENSARBETE

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Titel: Genomförbarhetsstudie om autonoma och fjärrstyrda fartyg

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Abstrakt

Detta examensarbete är utfört på uppdrag av företaget Foreship Ltd. Foreships specialitet är skeppdesign och ingenjörsvetenskap. Det fanns flera syften för detta examensarbete. Det första var att ta reda på vilken grad av autonom teknik som finns i fartyg idag och om det finns ett behov av autonoma fartyg. Det andra var att ta reda på vad som krävs för att autonom teknik ska implementeras och hur framtiden kan se ut. Det tredje var att ta reda på vad den bästa möjliga affärsmöjligheten för Foreship skulle vara, beträffande autonoma och fjärrstyrda fartyg.

Examensarbetet består av tre huvudsegment. Det första segmentet är teorin, som innehåller de teoretiska aspekterna samt bakgrundsinformation om implementering av autonom teknik. Det nuvarande autonominivån i fartyg, hur framtiden för autonoma fartyg kan se ut, juridiska frågor, säkerhetsfrågor och tekniska frågor är viktiga aspekter i detta segment. Det andra segmentet är intervjuerna. Kvalitativa intervjuer genomfördes med experter som arbetade inom olika områden i den maritima industrin. Syftet med detta är att få olika perspektiv på saken.

Det tredje segmentet är resultatet och slutsatsen. Resultatet innehåller en slutsatsats av teorin och intervjusegmenten samt ett affärsmöjlighetsförslag for Foreship. Slutsatsen visar att det finns behov av autonom teknik men det finns flera hinder att övervinna.

Språk: engelska

Nyckelord: autonoma, fjärrstyrda, MASS

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Nimike: Autonomisten ja etäohjattujen alusten toteutettavuustutkimus

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Tiivistelmä

Tämä opinnäytetyö on tehty yhtiö Foreship Oy:n tilauksesta. Foreshipin erikoisosaaminen on laivasuunnittelu ja insinööritaito. Opinnäytetyön tarkoitus oli useita. Ensimmäiseksi oli selvitettävä, millaista autonomisen tekniikan tasoa käytetään olemassa olevissa laivoissa ja onko ylipäätään tarve autonomisille laivoille. Toiseksi oli selvitettävä vaatimukset siihen, että autonominen tekniikka toteutetaan ja miltä tulevaisuus voisi näyttää. Kolmanneksi oli selvitettävä mikä olisi paras mahdollinen kauppamahdollisuus Foreshipille, koskien autonomisia ja kauko-ohjattavia aluksia.

Opinnäytetyö koostuu kolmesta pääosasta. Ensimmäinen osa on teoria, joka sisältää teoreettiset näkökohdat sekä taustan autonomisen tekniikan toteuttamiseen. Nykyinen autonominen taso laivoissa, miltä autonomisten laivojen tulevaisuus voisi näyttää, juridiset kysymykset, turvallisuuskysymykset ja tekniset kysymykset ovat tärkeitä näkökohtia tässä osassa.

Toinen osa on haastattelut. Laadullisia haastatteluja suoritettiin eri laivateollisuuden alan asiantuntijoiden kanssa. Haastattelujen tarkoitus oli saada eri näkökulmia asiasta.

Kolmas osa on tulos ja johtopäätös. Tulos sisältää johtopäätöksen teoriasta ja haastatteluosasta sekä ehdotus kauppamahdollisuudesta Foreshipille. Johtopäätös osoittaa, että autonomiselle tekniikalle on kysyntä, mutta pitää selvitä useista esteistä.

Kieli: englanti

Avainsanat: autonominen, etäohjattu, MASS

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Abbreviations

COLREG – Convention on the International Regulations for Preventing Collision at Sea

IMO – International Maritime Organisation

MASS - Maritime Autonomous Surface Ships

MRC – Minimum Risk Conditions

MSC - Maritime Safety Committee

MUNIN - Maritime Unmanned Navigation through Intelligence in Networks

SVAN - Safer Vessel with Autonomous Navigation

SOLAS – International Convention for the Safety of Life at Sea

1 Introduction

Autonomous and remote-controlled vessels is a hot topic today. In an era where artificial intelligence is closer to reality than ever before, it is no wonder that people believe that this is the next step in the development of marine technology. There are already unmanned aerial vehicles and self-driving cars but there are no unmanned vessels. The oceans are big and there is not a lot of traffic so there is plenty of room to navigate. There are so many different possibilities in implementing this kind of technology and no one knows for sure what the future will hold. The future of maritime might be autonomous technology but in what form. No matter how fascinating or cool new technologies are, there is always the question of necessity. New technology needs to replace but more importantly improve upon whatever was before and this is also the case with autonomy. An autonomous vessel does not necessarily need to be completely controlled by a computer, there are other ways of implementing it.

By replacing the crew or at least some of them with autonomous or remote-controlled technology for example could save money because of a smaller crew. There may also be more space for cargo and the developers of this technology argue that it will also be safer and there will be less accidents. The biggest reason for accidents on the oceans is caused by human errors, so by limiting that factor could increase safety. But there will be other new risks and challenges that comes with autonomy.

There are those who do not believe that autonomous vessels or other autonomous vehicles are the future for one reason or another. There are still a lot of things to figure out and people hesitate to put their complete trust in a computer handling everything when there potentially could be human lives at stake. Further research and careful testing are the only way of progressing and finding out to what degree autonomy could be implemented. The thesis is written on behalf of the company Foreship Ltd.

1.1 Problem area

The maritime industry is always advancing, and actors in the industry are trying to find new solutions to make vessels more efficient in all thinkable aspects. Companies need to comply with the stricter emission policies that is likely going to be implemented in the future to minimize emissions. Companies are also trying to develop their vessels to minimize the running costs and at the same time increasing or at least staying on the same efficiency level.

Autonomous and remote-control technologies could very well be the solution. But autonomy is a new and unproven concept in the maritime industry. There are companies that are on the verge of implementing autonomous and remote-control technology. In a few years there could be a whole new market emerging.

The problem is the uncertainty and the limited knowledge about autonomous vessels as a whole in the maritime industry.

1.2 Purpose

This thesis is written on behalf of Foreship Ltd. The company is experts in naval architecture and marine engineering. Autonomous vessels might be a big part in the future of the shipping industry. There are multiple points of purpose in this thesis. The first is to find out what degree of autonomy exists today and if there is a need for autonomous and remote-controlled vessels. The second is to find out what needs to happen for autonomous and remote-controlled vessels to become a reality and what the future could look like. The third is to evaluate possible business opportunities for Foreship, regarding autonomous and remote-controlled vessels. The thesis serves as a market study as well as an assisting document in consulting work regarding autonomous and remote-controlled vessels.

1.3 Foreship Ltd

Foreship is a company that specializes in ship design and engineering. The company was founded in 2002 by three persons and today they have over 100 employees in seven offices. These offices are located in Finland, Estonia and USA and a new office is opening in Hamburg (Germany) in the year of 2020. The services include consulting, conversions, concept design, basic design and detail design among other things. The working team at Foreship include naval architects, marine engineers, electrical engineers, HVAC engineers, structural engineers and machinery engineers. Foreship’s main projects are conversions of large cruise ships but they also deal in other projects, such as ship newbuilding, designs for cargo ships and luxury yachts, scrubber installations and consulting jobs. (Foreship Ltd., 2020)

1.4 Delimitations

This is a very vast subject and there are many different points and angles that could be included in this thesis. As this is a feasibility study, it will not go deep into how the different technologies work in autonomous and remote-controlled vessels. The focus will instead be on what technologies are used and what technologies needs to be developed. The same principle will be applied to the legal aspects. DNV GL is the only classification society mentioned in this thesis as they have created an in-depth guide regarding autonomous as remote-controlled vessels.

In this thesis the focus is on the bigger vessels. Such as passenger ferries, cruise ships and cargo ships. Small vessels that are for private use will not be included.

2 Implementation of autonomy

There are those that have the impression that autonomy means that for example cars, planes, trains and vessels are completely controlled by a computer, but this does not necessarily need to be the case. Autonomy can be implemented in smaller parts to make it easier for the crew of a vessel, to help them with certain aspects like docking for example.

Autonomous and remote-controlled vessels are both unmanned but there is a difference. Autonomous vessels navigate with the help of computers, algorithms and sensors whereas remotely controlled vessels are being piloted from a control station somewhere on shore. These two types of unmanned vessels are often mentioned together as a future solution for sea voyages, which means that they are not mutually exclusive. Both are probably going to feature in the vessels that implements these kinds of technologies.

There have already been a few actual implementations of autonomy and remote control and there are more coming in the future. Finland and Norway are in the driver seat right now, when it comes to unmanned vessels. Companies like Rolls-Royce, Kongsberg and Wärtsilä among others, are developing autonomous and remote-controlled technology. Rolls-Royce commercial marine was acquired by Kongsberg Maritime in April of 2019.

2.1 Falco

The ferry Falco which Rolls Royce and Finferries call *"the world's first fully autonomous ferry"* (Rolls-royce, 2018) was a part of the SVAN project in 2018. The ferry usually transports cars and passengers between the islands Parainen and Nauvo in the archipelago of southwest Finland. The demonstration of this autonomous ferry was done in December 2018 with 80 specially invited people observing onboard. The ferry is equipped with advanced sensors that helps it alter the speed when facing obstacles in the water or when closing in on the quay as well as docking by itself. The Falco navigated by itself on the journey to the other Island and was remotely controlled on the way back. There was a remote operating centre about 50 kilometres away where the captain first monitored the autonomous trip and then he also took control over the ferry from there. (Rolls-royce, 2018)

Figure. 1 The captain overlooking and steering the ferry Falco. (Lundqvist, 2018)

2.2 Wärtsilä & Folgefonn

Wärtsilä is a big actor in the marine industry. They handle basically everything in marine technology, such as cruise ships, ferries, fishing vessels, merchant vessels, navy vessels, offshore structures, ship design, special vessels and yachts. For example, a lot of the biggest cruise ships run with Wärtsilä's engines. They are also taking part of the autonomous shipping future and are trying to develop autonomous systems. (Wärtsilä, 2020)

Wärtsilä together with Norwegian operator Norled completed an autodocking test in the beginning of 2018. The tests were done with the ferry Folgefonn, an 85 metres long, 1182 tons, hybrid powered passenger and car ferry servicing in Norway. It was built in 1998 and in 2014 Wärtsilä installed wireless inductive charging technology. Folgefonn uses vacuum docking technology, which means that the vessel is kept at the dock with the help of suction. (Farnsworth, 2018)

The autodocking process starts at about 2000 metres from the berth. The software takes full control of the ferry and gradually slow the speed and activates the line-up and docking manoeuvre by itself. The process can also be used in reverse for departures. This allows the ship officers to shift their focus on solely overseeing the surrounding area during the docking phase and this will according to Wärtsilä improve the safety. Manual control is possible at any time if the need arises, but that was not necessary during the testing. These tests were carried out in April. (Wärtsilä Corporation, 2018)

In the end of 2018, further tests were carried out. This time the test was for fully autonomous manoeuvring from dock to dock. The ferry left the dock and manoeuvred its way out of the harbour and sailed to its destination and docked there without any human interaction. The process was done with the help of a series of tracks and waypoints, and GNSS (Global Navigation Satellite System) was used as the main sensor. (Wärtsilä Corporation, 2018)

2.3 Kongsberg & Kongsberg Maritime

Kongsberg is a global technology group that has its roots in the city of Kongsberg in Norway. They do work for organizations including maritime, digital, defence and aerospace. 80 % of their business is ocean technology. Kongsberg Maritime focus on developing everything from the core digital system to the propellers of ships, as well as everything from planning and designing to maintenance and service. Kongsberg Maritime is one of the leaders when it comes to autonomous vessels with their project Yara Birkeland. (Kongsberg maritime, u.d.)

2.4 Yara Birkeland

Kongsberg together with Yara international are working on the world's first fully electric and autonomous container ship. It is a 120 TEU (Twenty-foot Equivalent Units) open top container ship. Yara Birkeland is about 80 metres long and 15 metres wide. The service speed will be six knots and max speed 13 knots and it will be fully battery powered with a battery pack of 7-9 MWh. Three different operational centres are planned to handle the operation of Yara Birkeland. The ship is going to be delivered in 2020 and will first be navigating manually from a detachable bridge and then gradually move towards fully autonomous operation in the year 2022. (Kongsberg maritime, Yara Birkeland)

Figure 2. A concept image of the ship Yara Birkeland (Kongsberg maritime, Yara Birkeland)

2.5 Föri

The latest Finnish project in the unmanned vessels category, is being conducted with the ferry Föri. This small ferry is operating in the city centre of Turku in the Aura river. Föri only takes pedestrians and the trip only takes a couple of minutes. The tests will be conducted during the winters of 2020 and 2021. During these periods the ferry will collect data using sensors. The data will create algorithms based on the various obstacles and interferences that the ferry encounters during the many trips it makes every day. Föri will be operated manually as usual during this period and the data collected will then be used to develop a new completely automated ferry to replace it. The data collected can also be used in future research and the development of navigational algorithms for autonomous vessels in general. (Nyqvist, 2020)

2.6 Possible implementations

There are many potential ways to implement autonomy in the shipping industry. The degree of autonomy and remote-control implemented could vary depending on the type of vessel and its purpose. There are ways to implement autonomy without the vessels being completely controlled by it. Vessels could be remotely controlled from operation centres on land. Completely autonomous vessels will most likely include remote-control operations as an additional way to navigate. In case there is a need for a captain to operate the vessel, for example when the vessel is about to dock or if something unexpected happens during the voyage. Autonomous and remote-controlled operations could also be just an additional way of controlling a vessel without removing the manual manned operations, assisting the crew to increase safety and optimize operational efficiency. This will most likely be the most common way of implementing autonomy in the shipping industry.

Unmanned vessels need to minimize maintenance required because on-board repairs while out at sea would cause major complications. Therefore, it would be necessary to replace some of the mechanical moving parts of machinery with battery powered systems. This will however limit the distance the vessels will be able to travel, which mean at this stage completely autonomous vessels would be best suited to coastal operations. Also, because autonomy is so new and unproven, there is a high possibility of technical issues in the first vessels in operation. If an unmanned vessel would be out on the Atlantic and something went wrong, it would take days to reach it while the vessel is just drifting about on the ocean and that is not feasible. The first completely autonomous and remote-controlled vessels in everyday operation could be ferries and small cargo ships as they usually travel short distances. (Sames, 2017)

2.6.1 Ferries and small cargo ships

The majority of the tests that has been done are with a small vessel like a ferry. The reason for this is the short distance that a ferry usually travels which makes for a relatively safe testing opportunity in a day to day operation environment. This has been demonstrated by the ferries Falco and Folgefonn. This suggests that there is a potential for ferries to be the first vessels to implement autonomous technology. (Moore, 2019)

2.6.2 Cruise ships and large cargo ships

The implementation of autonomy and remote-control may be vastly different in bigger vessels, such as luxury cruise ships and large cargo ships that travels great distances over several weeks in some instances. One autonomous concept that might be used on these kinds of vessels is some form of the autodocking process. In the harbour there is a great risk of collision because of the limited water space and heavy vessel traffic. The autodocking system could start guiding the ship a few kilometres from the harbour and dock it safely while the crew has more time to focus on other safety aspects, as Wärtsilä did with the ferry Folgefonn. The rest of the voyage would be controlled manually in this case. (Sames, 2017)

There is a big question mark when it comes to huge cruise ships being completely autonomous, as there are human passengers' lives at stake which is not the case with container ships. There is also the issue of long sea voyages with autonomy or remote control as described in the introduction of this chapter. There are doubts about cruise ships ever being fully autonomous or even fully remote-controlled, but there are other ways for this kind of technology to be of use. Partial autonomous control could be implemented to help witch certain aspects of the voyage. The question is, is it necessary or is it just an unnecessary expense. (Dubay, 2019)

The difference between cargo ships and cruise ships are the cargo. The cargo of the cruise ship are humans and that means there needs to be a lot of crew to serve them in all imaginable ways. The Oasis of the seas, for example, which was built in Turku and had its maiden voyage in December 2009, takes 6296 guests and 2165 people in the crew. If the crew number could be taken down with autonomous technology so that there would be more space for passengers, it would save and make money at the same time. (Oasis of the seas, 2012)

2.7 Reasons for implementation

Autonomous and remote-control technology might replace the old manually controlled vessels to some degree but for this technology to be viable and for it to be used at all, it needs to bring improvements to the already existing navigational system. The project MUNIN (Maritime Unmanned Navigation through Intelligence in Networks) explains the potential ways autonomy could improve the shipping industry. MUNIN is a research project that was co-founded by the European Commissions under its Seventh Framework Programme. The goal of the project was to make a feasibility study about autonomous technology for vessels. (MUNIN, 2016)

2.7.1 Safety

Human errors cause at least 75 percent of marine liability losses. For example, a major accident that causes the vessel to run aground and causes a wreck, can have catastrophic consequences with the crew and passengers getting injured or even death as a worst-case scenario. Additionally, removal of the wreck costs a fortune as well as the losses of income due to the cargo being damaged. There might also be the environmental concern if some sort of pollution leaks out into the sea from a large cargo ship delivering oil for example. (Frith, 2017)

The implementation of autonomous and remote-control technology in some form could reduce this number because the human error factor would be taken away completely or at least minimized.

2.7.2 Economical

Companies that invest in new technologies and vessels in this case want them to be more efficient than what they had before. The vessels need to be able to transport more cargo at the same time as it is costing less to operate. It is all about cost efficiency when it comes to making money as a company. Autonomous technology could help with both increasing room for cargo as well as reducing the costs of operation. An unmanned cargo ship without the need for a bridge and living quarters for the crew could increase the cargo capacity as well as reducing the cost as there is no need for wages in the case of the vessel being completely autonomous. A remote-controlled vessel could still save money because the crew could be reduced substantially as the size of the remote operating crew could potentially only be a couple of men strong. Other factors include slower sailing speed and more efficient operating. This will reduce the amount of fuel needed and thus reducing the costs even more. (MUNIN, 2016)

2.7.3 Ecological

Countries and the EU (The European Union) are trying to lower the emission levels and this might cause countries to put restrictions on companies to hold them to a certain emission level. Autonomous and remote-controlled vessels might reduce the fuel consumption by reducing the sailing speed of the vessel. The MUNIN project points out that a medium sized bulk carrier can save up to 50 % fuel by reducing the speed by 30 %. That suggests that this could be a viable way of reducing pollution in the shipping industry. The reason why this is not implemented today is the crew's wages that would rise because of the longer voyage and therefore not be feasible economically. A completely unmanned vessel however could utilize this to save money and have less of an impact on the environment. (MUNIN, 2016)

2.7.4 Social

The amount of goods transported by vessels are growing every year and the need for more vessels and seafaring personnel are increasing. The seafarer career is perceived as unattractive despite the demand for more workers. This is due to the social disconnect following long voyages at sea. Autonomous technology could introduce an alternative way for the seafarer career by allowing the crew members to do their jobs from shore instead. Operation centres on shore that functions as a bridge from where the crew can remotely control and monitor the vessel and by the end of the workday can go home to their friends and family. (MUNIN, 2016)

3 Legal issues & Safety

Autonomous and remote-controlled vessels present a lot of different challenges before implementation becomes a reality. The most challenging part might be the legal side. The International Maritime Organization and DNV GL Maritime are two of the biggest actors in the maritime industry when it comes to regulations and guidelines. There are no standards or regulations for autonomous shipping as of this date. There are some guidelines made by IMO and DNV GL, but they have not yet established anything concrete. This is because there is still much to figure out regarding all the legal aspects.

3.1 International Maritime Organization

IMO is a specialized agency of the United Nations that is responsible for safety, security and environmental performance when it comes to the shipping industry. IMO or IMCO (Inter-Governmental Maritime Consultative Organization) was established in 1948 by an international conference in Geneva but in 1982 the name was changed to IMO. They entered into force in 1958 and had their first meeting the following year. (IMO, 2020)

In IMO´s strategic plan (2018-2023) there is a key Strategic Direction that states, “Integrate new and advancing technologies in the regulatory framework”. In 2017 several Member States proposed to include the issue of MASS, this would be done with so called scoping exercises. The target for these scoping exercises to be done is 2020. (IMO, 2020)

In June 2019 the MSC approved Interim guidelines for MASS trials at their 101^{st} session. The trials can only be conducted under safe circumstances. There needs to be risk identifications and procedures to reduce risks to keep everything as safe as possible. All personnel involved in the trials of MASS need proper qualification. The result of these trials will be reported to MSC 102 in May 2020. (IMO, 2020) SOLAS and COLREG are two conventions that IMO need to amend in great detail before autonomous and remote-controlled vessels can be allowed to sail internationally.

3.1.1 SOLAS

The SOLAS (International Convention for the Safety of Life at Sea) convention is globally considered as the most important treaty regarding safety of merchant vessels at sea. The first version of SOLAS was created in 1914 following the Titanic disaster. The second in 1929, the third in 1948 and the fourth in 1960. The 1974 version that exists today include the tacit acceptance procedure. This means that the current SOLAS can be updated and amended. *“The main objective of the SOLAS Convention is to specify minimum standards for the construction, equipment and operation of ships, compatible with their safety.”* (IMO, 2020)

There are several issues here including fire extinguishing capabilities and accident responding that requires reviewing for MASS. (IMO, 2020)

3.1.2 COLREG

The COLREG (Conventions on the International Regulations for Preventing Collisions at Sea) convention which took place in 1972 replaced the Collision Regulations of 1960. Which was adopted at the same time as the 1960 SOLAS convention. The COLREGs consists of 41 rules that are divided into six sections. Rule 10 is arguably the most important rule as it deals with traffic separation schemes. Rule 10 gives guidance in determining safe speed and the risk for collision among others. The COLREG also includes various issues that needs to be looked at regarding to MASS. For example, communication between vessels approaching each other to prevent collision. (IMO, 2020)

3.2 DNV GL

DNV GL provides risk management and quality assurance services to the maritime, oil and gas, and power and renewable industries. DNV GL – Maritime is the world's leading classification society when it comes to the maritime industry. They handle all vessel types and offshore structures. (DNV GL, 2020)

DNV GL created a class guideline document for autonomous and remotely operated vessels in September 2018. In this document, DNV GL points out that IMO has not yet come up with any regulations regarding unmanned vessels. IMO needs to establish a safety framework before these technologies can be implemented in any form to international shipping. Since this documents release, IMO and MSC has approved some basic guidelines for MASS trials and has started looking at different treaties such as SOLAS and COLREG (IMO, 2018). The document however mentions that nations and regions are free to support the introduction of unmanned vessels within their own waters. Upholding safety expectations still apply, and this guideline document serves as a guide for safe implementations. DNV GL states that this guide will be expanded upon in the future when the technology and research advances and when more real-life tests and implementations have been made. (DNV GL, 2018)

3.2.1 DNV GL Class guideline: Autonomous and remotely operated ships

This class guide document is a good base when it comes to safety and figuring out how to approach things legally. The main principles that DNV GL follow in their assessment of MASS are presented below.

- equivalent safety
- risk-based approach
- operational focus
- minimum risk conditions
- functional focus
- degrees of automation and human involvement per function
- system engineering and integration
- design principles
- software engineering and testing
- cyber security

(DNV GL, 2018)

According to the document, autonomous or remote-controlled vessel need to have at least the same level of safety equivalent or better than the vessels that exists today. It is important to not only think about the consequences for the crew onboard but also consider the consequences for the assets, the environment and the public. Autonomous and remote-controlled vessels are viewed by some to have reduced safety because of the absence of humans onboard. Certain safety aspects such as onboard crew safety measures can be eliminated due to the crew not being present, (for example, lifeboats and lifejackets). Thus, these aspects can be removed from the planning process. On the other hand, there are other aspects that have increased risk factors. The document specifically mentions fire safety and specifically fire extinguishing capabilities, as a big factor on the safety level on a completely unmanned vessel. This clashes with DNV GL's approach of equal or better safety level. This is just one example of the many factors that needs to be figured out before an international unmanned vessel is put into service. (DNV GL, 2018)

3.2.2 Design principles

DNV GL identifies a few key principles that are necessary for implementation of autonomy in vessels.

1. *Maintain a safe state.* In the case of an unforeseen incident such as fire, flooding or a failure in onboard systems, the vessel should remain in a safe state and not be a danger to the surrounding environment. In all possible scenarios the vessel should enter and maintain a MRC.

2. *Maintain normal operation.* The vessel should maintain normal operation in case of an anticipated failure.

3. *Redundancy and alternative control.* In the event of a MRC the vessel should not rely on only one system bust instead mitigate by applying redundancy principles, e.g. two steering systems or alternative control capabilities

4. *Independent barriers.* Systems or components that are designed to comply with the prior principle should not be affected by the failure of the primary systems or components. The incident or failure cannot affect both the primary and the redundancy system. This principle is especially important in the event of a flooding or a fire.

5. *Self-contained capabilities on board.* Failure of remote systems, normal operation and safe state should be maintained by systems or personnel onboard.

6. *Self-diagnostics and supervision.* Undetected failures should be prevented by sufficient supervision using advanced alert management functions and enhanced diagnostic functions.

(DNV GL, 2018)

3.3 Degrees of autonomy

The definition of an autonomous vessel is a seaborn vessel that is navigating the seas without human interaction, but this is not always the case as stated earlier. There are different degrees to autonomy when it comes to MASS. Companies, organizations and people have their own definition of autonomy and on the degrees of autonomy and this may cause some confusion. In order for MASS to be introduced on a global scale there needs to be clear definitions of the different levels of autonomy. The new set of rules and regulations implemented concerning MASS have to vary according to the level of autonomy of a vessel.

In December 2018 MSC had their 100th session and they made progress in the regulatory scoping exercise on MASS. The MSC created four different degrees of autonomy for the scoping exercise. The different degrees are presented below.

- ***Degree one:*** *Ship with automated processes and decision support:* The crew is present and operating the vessel with the assistance of the automated systems. Some functions may be automated and not monitored under certain circumstances. The crew is ready to take control if necessary.

- ***Degree two:*** *Remotely controlled ship with seafarers on board:* The vessels is operated remotely. The crew is on board and ready to take control if necessary.

- ***Degree three:*** *Remotely controlled ship without seafarers on board:* The vessel is operated remotely. No crew on board.

- ***Degree four:*** *Fully autonomous ship:* The vessel is completely autonomous and operating by itself. The vessel can determine the best approach in all circumstances and make the appropriate decision.

(IMO, 2018)

DNV GL expanded upon this concept with four different types of concepts in their guideline document. The document even stated that these four concepts could be linked with IMO: s list for MASS scoping exercises. The concepts are presented below.

- *Decision supported navigational watch.* The concept of this is an enhanced decision support system that could help the crew in charge of the navigational watch. The idea is that the system could cover duties normally done by the crew, look-out for example. The purpose is to increase the safety.

- *Remote navigational watch.* The concept of this is a remote-control centre that covers the conventional crew in charge of navigational watch. This means that there are no crew navigating and communicating on board.

- *Remote engineering watch assisted by personnel on board.* The concept of this is a remote-control centre that covers the crew in charge of the engineering watch. This requires crew on the vessel to do their assigned tasks with the assistance from the remote-control centre.

- *Remote engineering watch.* The concept of this is a remote-control centre that covers the crew in charge of the engineering watch. This would require no crew on the vessel and the remote-control centre would perform all the necessary actions.

(DNV GL, 2018)

4 Technology

Vessels that are unmanned need a way to operate. The vessels need to respond to other vessels and adjust accordingly to avoid collisions. Also, they must be able to avoid grounding and adjust their speed and course depending on the weather. This is done by using different kinds of sensors, AI software, algorithms and monitoring the situation when it comes to remotely controlled vessels.

Surface Systems (Shipboard)	*Sensor Type*	*Data Class*
Aids to Navigation (ATON) - Physical	Receiver	Imagery
Aids to Navigation (AIS) - AIS	Receiver	Data
Aids to Navigation (VATON) - Virtual[B,C]	Data Object	Data
Automated Identification System (AIS)	Transceiver	Data/Imagery
Electronic Chart Display Info System (ECDIS)	Data Object	Data
Inertial Navigation[C]	Instrument	Data
Laser Imaging (LIDAR)[C]	Instrument	Imagery
Marine Radar (X/S band) with ARPA	Transceiver	Imagery/Signal
millimeter Radar[C]	Transceiver	Imagery/Signal
Visual (video)[C]	Receiver	Imagery
Infrared (IR)[C]	Receiver	Imagery
Audio (sound)	Receiver	Signal
Unmanned Aerial Vehicle (AUV)[C]	Receiver	Imagery
Subsea Systems (Shipboard)		
Echosounder	Transceiver	Imagery/Signal
Navigation Sonar[C]	Transceiver	Imagery/Signal
Side Scan Sonar[C]	Transceiver	Imagery/Signal
Unmanned Underwater Vehicle (UUV)[C]	Receiver	Imagery
Space Systems (Remote)		
Automatic Identification System (AIS)[C]	Receiver	Data/Imagery
Global Navigation Satellite System (GNSS)	Receiver	Data
Meteorological and Ocenographic (METOC)	Receiver	Data/Imagery
Optical Imaging[C] (non-METOC)	Receiver	Imagery
Synthetic Aperature Radar (SAR)[C]	Receiver	Imagery

Figure 3. A table of the sensor types used in maritime operation. (Wright, 2019)

4.1 Sensors

The main objective of a sensor is to gather specific data that then can be used in a variety of different ways. In the case of an autonomous navigation system, the different kinds of sensors gather information that is then used for navigational purposes. The different sensors gather different data about the surrounding environment. The AI then uses that information to navigate or help humans to navigate the vessel.

The sensors used on a completely unmanned vessel must have the equivalent or better sight and hearing of seafarers. A 360° vision of the landscape in four dimensions around the vessel is necessary. The ability to see underwater in front of the vessel to sense potential dangers to prevent grounding for example. The ability to pick up sound signals from nearby vessels is also required. Weather instruments can provide real-time data on the weather to help with navigation. (Wright, 2019)

As an example, the sensors used by Yara Birkeland are presented below.

- Radar
- Lidar
- AIS
- Camera
- IS camera

(Kongsberg maritime, Yara Birkeland)

4.2 Connectivity & Communication

It is essential for unmanned vessels to have constant communication with a control centre on shore available. Therefore, broadband satellite connectivity is an important aspect for autonomous and remote-controlled vessels. Today there is a lack of connectivity on the seas, but that could change. Reports show that the amount of satellites launched into earth's orbit could be tripled in the next ten years. Satellites are used in maritime operations and an increase in the amount of satellites in the sky would improve the broadband access around the world. (Wright, 2019)

As an example, the communication systems used by Yara Birkeland are presented below.

- Maritime Broadband Radio
- Satellite Communication
- GSM

(Kongsberg maritime, Yara Birkeland)

4.3 Artificial Intelligence

Because of technology the risks of accidents are reduced on the seas. For example, radars help the captain and crew navigate but there are still 3000 collisions each year. The majority of the collision occur in crowded waterways and when the visibility is poor. In low-visibility conditions, humans have to rely on technology to be able to identify objects that could cause a collision. The problem is that most of the vessels do not have the systems capable of doing this and that is because it does not exist yet. The larger the vessel the harder it is to navigate safely. Advanced sensor and an AI could be the solution. The problem with installing multiple advanced sensors is that the crew easily becomes overwhelmed with all the data coming from the sensors and thus the data becomes redundant. There is also the possibility that the crew will not understand the info from the sensors and do not know what to do with it. This is where the AI would come in. The AI helps with compiling all the data from the sensors into useful information for the crew. This would give the vessel long range visibility even in harsh weather. An AI capable of doing this are in development today and vessels are implementing it to minimize the potential for disasters. This could be the first step towards an AI that could control a vessel completely without human interaction. (Tunnicliffe, 2019)

5 Cybersecurity

Piracy has been a problem since the first vessels were launched in the antique era and there are still pirates today that causes problems for vessels across the seven oceans. Today there is a very new possible way of piracy in the form of cyberattacks.

As technology advances, so does the potential for cyberattacks in various ways. This is the case for everything that is digitalized, automated and connected to the internet. Cyberattacks do not only happen from far away through networks but also by malwares via removable media from people that has access to the systems on board of a ship for example. With autonomy and remote control implemented to vessels, the risk of cyberattacks and the need for cybersecurity will increase. Risk assessment need to be carefully made to identify possible threats and vulnerabilities as well as plans on how to respond and recover from cyberattacks. Development of protection and detection measures to reduce the risk of data being exploited is also needed. Autonomous technology means more digitalization and that makes autonomous vessels vulnerable to cyberattacks. In 2018 it took 140 days on average from the day of the cyberattack to detecting it. In 2015 it was 205 days, so there has been an improvement, due to new and better technology but sometimes it can take years to detect the breach. (BIMCO, et al. u.d.)

5.1 Risk assessment of cyberattacks

The development of a functional and secure protection system against cyberattacks is the key to cybersecurity. The key part of a functional cybersecurity system is identifying every possible risk, threat and vulnerability so the protection system can be as versatile as possible.

There are three different categories for identifying a threat. These are presented below.

- *Group* – These are the different people or organizations that would want to do some form of harm to the vessel or the company through cyberattacks. These include activists, criminals, opportunists, states, state sponsored organizations and terrorists.

- *Motivation* – These are the possible motivations and reasons for the groups to make a cyberattack. Possible motivations include commercial espionage, distribution of operations, espionage, financial gain, industrial espionage, political gain, reputational damage or just for the challenge

- *Objective* – These are the possible objectives and goals of an cyberattack. Some examples of the objectives include destruction of data, selling or ransoming stolen data, financial gain, publication of sensitive data, media attention, gaining knowledge and so on.

(BIMCO, et al. u.d.)

5.2 Types of cyberattacks

The different types of cyberattacks needs to be identified in order to create a valid cybersecurity system. Cyberattacks can be categorized in two different categories, untargeted attacks and targeted attacks.

- *Untargeted attacks*, company or vessels systems and data are one of many potential targets in an attack.

- *Targeted attacks*, company or vessels systems and data are the intended target for the attack.

(BIMCO, et al. u.d.)

5.2.1 Untargeted attacks

There are a lot of different tools and techniques that may be used in an untargeted attack. A few examples are presented below.

- *Malware* – Ransomware, spyware, trojans, viruses and worms are the most common types of malware (malicious software). The main purpose of malware is to access or damage systems and data without anyone noticing. Malware can be triggered locally or remotely.

- *Phishing* – Sending emails containing hyperlinks to fake websites or asking for sensitive or confidential information to many targets.

- *Water holing* – Creating a fake website to manipulate visitors

- *Scanning* – Randomly attacking targets on the internet

(BIMCO, et al. u.d.)

5.2.2 Targeted attacks

Targeted attacks often have more target specific tools and techniques. A few examples are presented below.

- *Social engineering* – A technique used to manipulate people in the company for example into breaking security procedures, this is done mainly through social medias.

- *Brute force* – The attacker tries to access the systems by systematically trying many passwords until getting the right one.

- *Denial of service (DoS)* – Hindering a user to access information, typically by overwhelming a network with data.

- *Spear-phishing* – Similar to phishing but this is target specific emails that contains malware or links to direct downloads of malware.

- *Subverting the supply chain* – Compromising equipment, software or supporting services.

(BIMCO, et al. u.d.)

6 Method

There are not autonomous or remote-controlled vessels in commercial use today. They are still very much in development. There has been some experiments and various tests done, and there is more planned in the future. This means that there are very limited real-life experiences that can be used. There are no books on this specific topic but there are quite a lot of factual articles, reports and writings online. The main sources for the theory are different companies and organizations that are in the maritime industry and are in some way involved with autonomous technology. Reports and studies about autonomous and remote-controlled vessels have also been used as sources in this thesis. Interviews were conducted as a way of getting information directly from experts in the maritime business.

6.1 Interviews

The interviews were conducted with the purpose to get information regarding autonomous and remote-controlled vessels. The interviews were conducted with three different interview subjects who worked in different areas of the maritime industry. This allowed for different perspectives on the matter.

6.1.1 Method for interviews

Qualitative interviews were conducted for this thesis. Qualitative interviews are similar to a conversation between two individuals. A one-on-one interview offers the possibility of getting a more detailed and personal answer from the interview subject. (Kvale & Brinkmann, 2014) Therefore, interviewing a few specifically selected experts with knowledge about the topic would yield the most viable results.

When conducting qualitative interviews, it is important to have the right amount of interview subjects. If the amount is too low, it would be difficult to generalise or compare hypotheses. If the amount is too high, it would be difficult to get a detailed conclusion of the answers. (Kvale & Brinkmann, 2014) With this in mind, three interview subjects were selected and as mentioned earlier, the interview subjects work in different areas of the maritime industry. This resulted in detailed answers from three different perspectives and thus a generalisation could be compiled.

6.1.2 Questions for the interviews

The questions asked to the interview subjects were based on the research in the theory chapters. There were five main questions asked to all interview subjects. Additionally, one to three personal questions were asked based on the interview subject's working role.

Before the interviews started, the interview subjects were informed of the concept of the thesis. The interviewees were also asked to talk about their education and current job before the other questions.

6.1.3 Summarizing the answers

The interviews were recorded with the purpose of getting the best possible analysis of the answers. Recording the interview allows the interviewer to focus on the topic and dynamic of the interview. This also allows for the interview to be permanently stored for multiple reviews, which leads to the most accurate transcription of the answers. (Kvale & Brinkmann, 2014)

The interview results are a summarization of the answers given by the interview subjects. The answers have been interpreted into a more formal text, to make it easier for the reader to understand. The interpretations have been written into fluid texts, and the texts have been divided into paragraphs based on the questions.

6.1.4 First interview

The first interview was held with Johanna Salokannel who is a project manager for the MasterSIM project as well as a project coordinator for MAST! Institute. She is also conducting lectures in the Master of Engineering, autonomous maritime operations programme at UAS Novia. She has a bachelor's degree in master mariner and a master's degree in safety and security management.

The MasterSim is a project coordinated by Novia UAS. The goal of the project is to answer the needs from autonomous shipping and maritime digitalization trends related to remote operation. The idea is to develop a Remote Operation Centre (AMOC) that will function as an educational simulator as well as a research platform for remote operations of a vessel. AMOC will be located in the maritime academy Aboa Mare in Turku but can also be used for real-life testing purpose. (Aboa Mare, 2020)

The goal for the MAST! Institute is to develop a research platform for autonomous shipping and maritime digitalization and develop new solutions for autonomous shipping as well as ensuring future seafaring competence in that regard. Åbo Akademi University's Software Technology Research Lab and Novia's Maritime Academy, Aboa Mare are working together on this project. (Aboa Mare, 2020)

The questions asked to the interviewee are presented below.

1. Where and how do you think the first autonomous and remote-controlled vessels will be implemented in everyday use?
2. Do you think that there ever will be fully autonomous and remote-controlled vessels that sails between continents, such as cruise ships or large container ships?
3. What could the benefits be with autonomous and remote-controlled vessels compared to the conventional vessels that exists today.
4. What is preventing autonomous and remote-controlled vessels from being in use right now?
5. Are cyberattacks a bigger threat to autonomous vessels compared to vessels existing today?
6. How do you think the market will look like in the near future?
7. How do you think that a company like Foreship could take part in this market?

6.1.5 Second interview

The second interview was held with Jan-Erik Räsänen who is head of new technologies at Foreship since 2017. His job consists of finding solutions existing today and figuring out what the future of the maritime industry is going to look like. Before he joined Foreship he worked 10 years at ABB Marine and ports. There he mostly worked on energy efficiency items on existing ships, including items around energy management. He has a bachelor's degree in electrical engineering.

The questions asked to the interviewee are presented below.

1. What could the benefits be with autonomous and remote-controlled vessels compared to the conventional vessels that exists today.

2. What is preventing autonomous and remote-controlled vessels from being in use right now?

3. Are cyberattacks a bigger threat to autonomous vessels compared to vessels existing today?

4. How do you think the market will look like in the near future?

5. How do you think that a company like Foreship could take part in this market?

6.1.6 Third interview

The third interview was held with Pasi Roos. He is the safety and traffic director at Finferries. He has a seafaring background of 21 years and he has a master's degree in marine technology. Altogether he has over 26 years of experience in the seafaring business. He was the project manager of the SVAN project that was done with the ferry Falco.

The questions asked to the interviewee are presented below.

1. What was your part in the autonomous testing of the ferry Falco?

2. What could the benefits be with autonomous and remote-controlled vessels compared to the conventional vessels that exists today.

3. What is preventing autonomous and remote-controlled vessels from being in use right now?

4. Are cyberattacks a bigger threat to autonomous vessels compared to vessels existing today?

5. How do you think the market will look like in the near future?

6. Why is Falco not operating autonomously or by remote control after the successful SVAN project?

7 Interview results

7.1 Interview 1

Johanna Salokannel believes that the first autonomous vessels in use could be small passenger ferries that crosses a river or is transporting passengers a short distance. Trips that are straight and without much traffic. For example, ferries that operate in the archipelago where the trips are short, and they do not have to give way so much. She believes that remote piloting is going to be included in these vessels. It will take longer for the bigger ships because they do nnot travel between point A and point B. The ports have to rethink the infrastructure to be ready to receive autonomous vessels.

Salokannel believes that it is going to take a long time before big autonomous passenger ferries will be in use. It is such a big risk when there are passengers involved and there are so much that can happen. However, there is an interest in autonomous container ships because it can save money, by using less fuel and having less or no crew. The technology that exists today could enable autonomous vessels. The problem is the collision risks. There are other vessels, storms, connectivity issues among others that provides a difficult challenge to overcome. Large vessels like cruise ships and container ships do not need to be fully autonomous. Human performance can vary a lot from day to day, but automation technology is always efficient. Step by step vessels will become more autonomous by minimizing the time humans need to navigate. Technologies will increasingly help humans make decisions and do more tasks that were originally done by humans. There is the possibility that the big vessels never will be fully autonomous. Salokannel mentions that there are automation technologies in use already. For example, tracking pilot and the possibility for autodocking is being developed in the port of Turku.

Salokannel says that autonomous vessels could have less emissions because of the technology and because the vessels can reduce their speed. This ties into the economic benefits as well. The expenses can be lowered by using less fuel. For example, one-minute shorter docking process can save a lot of fuel. Autonomous technology can optimize performance. Decreasing the crew is another possible way of reducing expenses. However, investing in autonomous technology might be costly and it is not necessarily more cost effective. The safety aspect is also a possible benefit. The maritime industry has tried to eliminate the human error for a long time, without success. Accidents can be reduced with autonomous technology. Humans are bad at monitoring long boring jobs, especially at night as tiredness and boredom affect the performance. Machines are a good solution to that. If something unforeseen happens, humans need to take control because today the machines cannot handle it. Machines do not take shortcuts or make decisions that can lead to accidents. This is because the computer follows the route that was programmed. Then there is the issue of the social life of a seafarer. Salokannel says that seafarers might stay on the sea for up to six months and for a lot of people that is too long. This is no problem for a person who is single and enjoys life at sea but spending a long time at sea away from your family might be hard. For the people with family, remote-controlled vessels might be a solution to make the seafarer job more attractive.

When asked about why autonomous and remote-controlled ships do not exist today, Salokannel points out that there are no legislation, rules or regulations yet. There is no clear understating of who is the captain of an autonomous vessel. One of the problems is the legislation that exists are written for humans. They contain concepts like good seamanship, safe distance and ample time. These are not easy to change. The lack of connectivity coverage around the globe is another factor. The unmanned vessel always needs to be connected to a control centre, to ensure that everything is in order. Salokannel think that autonomous and remote-controlled vessels need a different engine room. The components used need to be very reliable. The vessels also need more than one engine system. Because if one fails there are no one to repair it and the vessel will be stuck in the middle of the ocean. This means that a vessel like this would likely be more expensive than conventional vessels. Companies might not see it as a worthwhile investment.

Salokannel believes cybersecurity is an important issue in these modern times, not only in autonomous vessels. Cyberattacks are a different kind of piracy. This is a form of piracy that does not include guns and boarding a ship. The people carrying out the cyberattacks needs to be skilled to hack into a system. As cybersecurity systems get better, the attackers will get better. When the first autonomous vessels are launched, they will attract criminals. They want to test their skills. She says that it might not be so difficult to break the connection to an autonomous vessel. Therefore, it may be important to make the ship itself as secure as possible. Another way could be hacking into the system and deny access to it and ask for a ransom. The cybersecurity system needs to be completely safe before autonomous vessels can be introduced.

Salokannel suggests doing feasibility studies as a way for Foreship to take part in the upcoming market of autonomous and remote-controlled vessels. Companies that are contemplating about investing in autonomous technology, needs facts to help with the decision. There are no historical data and the systems being tested now are completely new and unproven.

7.2 Interview 2

Jan-Erik Räsänen think the benefits are related to the ship type. Smaller road ferries might not benefit from more autonomous technology in the perspective of more safety and efficiency. The captain onboard manoeuvres the same short route all the time so having a computer controlling it might not be more effective and safer. However, bigger road ferries could benefit by reducing the crew and thus reducing operational expenses. The bigger ship types that operates between Finland and Sweden for example, already have the autopilot function. The big advantage for these types of ships could be autodocking. The biggest advantages and savings could be by having sensors, radars and lidars assess the approach to the peer. This is a time-consuming task, especially in harsh weather conditions. Anything that can save on manoeuvring would be a clear benefit considering safety and fuel saving. The faster the ships are manoeuvring during docking, the slower the ships can travel to its destination. Going 20.5 knots instead of 21 knots can save a lot of fuel. The idea is that the computer would take over the control of the ship and doing it in a safe and efficient manner.

Räsänen think that autodocking is the starting point, where he sees the most benefit. The safety aspect could be the most important one regarding cruise ships. The sensors can assess what the best approach is to have the docking sequence as short as possible. A computer could react faster than a human brain could. Unnecessary expenses could be minimized by avoiding collisions in the port area where the space is restricted. He thinks that the solution would be autodocking with sensors preventing unsafe circumstances from occurring.

When asked about why there are no autonomous or remote-controlled vessels today, Räsäsnen says in modern ships there are multiple levels of safety inbuilt on the system. The safe return to port is one safety function. There are 50 % redundancy items built into ships today. For example, there are redundant propulsion and redundant functionality in the PMS-system. Ultimately all this redundancy is built in a way that the ship is able to operate without any automation system in use. There are a lot of automatic functions as well as manual functions. Implementing all these safety aspects into autonomous or remote-controlled ships that accounts for all the different scenarios requires a tremendous amount of computational capacity and power. For example, redundancy aspects which counts as requirements from SOLAS, from administration, from classification are aspects that needs considering. Also connecting everything to sensors that are fast enough to react to any circumstance the ship might face. Enough capacity in a server system to take care of these things do not exist yet. It might work for smaller coastal vessels where there is not a huge amount of systems. A completely remote-controlled machinery room will take a long time implementing. Regulations exist today to make it possible to have a partly unmanned machinery room. This is the first step towards semi-autonomous areas of a ship he says. Regulations is also affecting the stage of autonomous technology. The regulations cannot keep up with the advancement of technology.

When asked if cyberattacks are a bigger threat to autonomous vessels, Räsänen says that it is two folded. There are companies that want to digitalize the transfer of data. Typically, one, two, three years ago the suppliers of electronic products onboard, would have their own connections and satellite communication methods he says. They would use the ships satellite connection to transfer data and thus use a lot of bandwidth from the ship. There are companies that offer the solution of centralizing the communication of the products. These companies take on the responsibility of transferring data on behalf of the suppliers. This could increase the possibility of cyberattacks because criminals would only need to focus on one path. However, Räsänen says that this could potentially make the ship more secure against cyberattacks. This is due to the reason that there is only one source that needs protecting. It is hard to know if all the supplier’s products are up to date regarding the cybersecurity. When there is multiple suppliers and multiple connection points there might be a bigger risk of successful cyberattacks. The company that would take care of the transfer of data have the possibility to set up and maintain a reliable cybersecurity system. This would be one enabler for autonomous and remote-controlled vessels. Ultimately, he does not believe the risk of cyberattack would increase for autonomous vessels if proper cybersecurity systems are in place.

Regarding autonomous ships in the near future, Räsänen says that it is hard to predict what the landscape will look like. The road ferries will be autonomous on a higher grade and maybe be remote-controlled. There will not be a huge amount of remote-controlled ferries in five years. The ships that require a higher degree of safety will only have a slightly higher degree of autonomous technology. He hopes that cruise ships would partly implement autodocking within 5 years. Big container ships will not change in the next five years. Coastal ships might be more autonomous than deep sea ships.

Räsänen believes that Foreship would be best suited for consulting work, regarding autonomous and remote-controlled vessels. Foreship could help the owners understand the complexity, the way it could be done and help the owners identify the right suppliers on the market. If a customer has been offered a solution, Foreship would assess the solution and guide the customer. The idea is that the company would be educated and be able to help on a concept level of all the details needed for the implementation of autonomous technology.

7.3 Interview 3

Pasi Roos believes the biggest benefit would be increased safety. This would be done by minimalizing human errors. Studies have shown that the human error causes most of the accidents. Roos says that he wanted Rolls-Royce to develop the autodocking function on their ferries, so the ferry could automatically connect to the linkspan when docking. Autodocking could improve safety in harsh weathers for example. The autodocking system can take over the docking process when the visibility is restricted, in the case of a blizzard for example. Autonomous technology could have a positive impact on the economic part. The fuel economy could be optimized with automation. The manning cost are high on ships so reducing that could lessen the expenses. By reducing or removing the crew and by partly or completely taking away the crew quarters, could compensate for the investment in autonomous technology. This could also increase cargo space.

When asked why there are no autonomous or remote-controlled vessels in use today, Roos says that regulations regarding autonomous vessels do not exist yet. The regulatory work needs to be done first and accepted worldwide before companies want to invest on a larger scale. However, locally in territorial waters, companies could start investing in and testing autonomous technology. There you are constricted only by local laws and regulations. But the shipowners are not convinced that the investment in new technology would be worth it. The standardisations are still missing. There are multiple suppliers of autonomous and automation technologies, but they do not fit together. Roos says that you must choose one manufacturer and go with them. Pricewise there is no competition yet. Finland and Norway are highly interested in autonomous technology in vessels. Japan is also interested because they have a lack of seafarers.

Roos thinks that the threat of cyberattacks against autonomous vessels are equal to that of conventional vessels. Cybersecurity is taken very seriously when designing autonomous vessels. Roos is not sure that is the case with conventional vessels in the shipping business of today. There is remote monitoring, but they might not have a good cybersecurity system. There are changes coming to the ISM (International Safety Management) code. The changes will include mandatory cybersecurity for ships in some form.

Regarding the near future market for autonomous vessels, Roos believes that there will not be major changes. Finferries have some upcoming projects involving autonomous vessels, but they are not ready for commercial use yet. This is partly due to the lack of regulations.

When asked about the ferry Falco, Roos says the Svan project with the ferry Falco was a success. The intention was not for the ferry to continue operating autonomously or by remote-control. The intention was to show the world that autonomous and remote-control operation with a vessel is possible. The autonomous system is still present in the ferry but Finferries has no plans to utilize them in the foreseeable future.

8 Result

There were multiple purposes for this thesis and therefore there are multiple conclusions that can be drawn from the research. Shipowners are always looking for ways to improve efficiency and lowering operational costs and it is likely that autonomous technology could be the solution. There are many possible benefits with autonomous technology but there are many obstacles preventing it from becoming a reality.

Despite the obstacles there seems to be a future for autonomous technology. It is expected that it will be implemented to some extent, but it is impossible to predict to what degree this would be. A business opportunity proposition has been made with these aspects in mind.

8.1 Analysis & conclusion

It is quite hard to predict the future of the maritime industry regarding autonomous and remote-controlled vessels. It seems that it might take at least five years before completely unmanned vessels will be in regular commercial use. Proper legislation is lacking at this moment which means there are no clear directions for companies that want to develop autonomous vessels. The development of legislation is slow, and technology is developing at a rapid rate, because of this it is a difficult challenge to establish anything concrete.

Both Salokannel and Roos pointed out that companies and investors might not see autonomous technology as a worthwhile investment at this time. One way forward is by doing test runs like Finferries did with the ferry Falco. The other way is by doing research and feasibility studies on autonomous technology. Finding out what can be done, what the limitations are and what is a worthwhile investment is key for the implementation of autonomous and remote-control technology.

8.1.1 Benefits

All three interviewees thought of the same main beneficial aspects in general, with a few variations. The focus on the most beneficial aspect altered between them. According to Räsänen the benefits could vary depending on the vessel type. Increasing safety seemed to be the central focus for all the interviewees. Reducing expenses in various ways and increase efficiency are the other main benefits.

All the interviewees talked to some extent about reducing fuel usage. This has two benefits as it will lower the expenses as well as reducing emissions. According to Räsänen and Salokannel this could be done by reducing the time of the docking process. By reducing time spent on the docking process it would save fuel, but this would also allow the vessel to travel with decreased speed to its destination and consequently also save fuel. This is the autonomous concept of autodocking. Autodocking could save fuel but could also make the process of docking safer, especially in harsh weather conditions when the visibility is restricted.

All three interviewees think that passenger ferries might be the first fully autonomous or remote-controlled vessels in commercial use. The reason for this is that these vessels travel short distances in a relatively safe environment. These ferries are also likely to be the first vessels that implement autodocking according to the interviewees. Roos believes that implementing autonomous technology in these ferries would increase safety because it would take away the human error. However, Räsänen thinks smaller ferries might not be safer, because replacing one person that has major experience in operating that specific ferry, might not be beneficial. The bigger passenger ferries could also benefit economically by reducing or removing the crew. The crew expenses would be reduced or eliminated completely and the need for a control bridge is eliminated. This would save both space and money.

Räsänen thinks that cruise ships could benefit the most by implementing autodocking. This would allow the ships to increase the docking efficiency and thus save fuel. Autodocking would also increase safety and decrease accidents in the ports. Salokannel seem to agree with this and adds that autonomous technology could help humans make decisions during navigation. There is a big crew on a cruise ship so the potential for lowering the expenses exist. However, most of them work in service and that cannot be replaced by technology.

Salokannel says there is an interest in implementing autonomy or remote-control on cargo ships. There is the possibility of removing the crew completely and thus removing the bridge. This would save on expenses as well as potentially increasing the cargo capacity. Autodocking could be of use in cargo ships.

8.1.2 Obstacles

Autonomous and remote-controlled vessels do not exist today and there are multiple reasons for this. The biggest factor is that the legislation is lacking as stated earlier. SOLAS and COLREG are the two main conventions that needs to be amended in order to comply with autonomous vessels. The challenge is categorizing the different degrees of autonomy in vessels and implement different regulations according to the level of autonomy. The matter of who is responsible on an unmanned vessel is an important aspect that also needs to be clear before implementation is possible.

The lack of developed autonomous technology is the other big factor that is hindering the advancement of autonomous and remote-controlled vessels. The major problems seem to be the lack of connectivity coverage and the lack of computational capacities of computers. The need for multiple engine systems on a fully unmanned vessel is also a challenging aspect in many ways.

The legal uncertainties and the technological limitations are big factors that makes companies and investors hesitant to invest in autonomous and remote-control technology.

8.1.3 The threat of cyberattacks

The threat of cyberattacks exists and it increases with every increase of the level of digitalization. The threat might not be greater for autonomous and remote-controlled vessels although it is certain that vessels with autonomous technology are more digitalized than conventional vessels. This entails that the level of autonomy dictates the level of cybersecurity.

There is a possibility for the first autonomous or remote-controlled vessel to attract cybercriminals. It is important to make a risk analysis about the potential ways the vessel could be exploited in a cyberattack. Hacking into the system and take control might be difficult but breaking the connection and blocking access to the vessel might not be that challenging for the cyber attackers. Unmanned vessels need to have proper physical breach protection as there are no humans onboard to protect the vessel.

A more centralized data transfer system opposed to digitalized products communicating in their own way, could make vessels less susceptible to cyberattacks. Changes that would make some level of cybersecurity mandatory might be coming soon to the ISM code.

8.2 Business opportunity for Foreship

Autonomous and remote-controlled vessels might be the future of the maritime industry. There is certainly a major interest in autonomous technology and there are clear benefits. As stated earlier it is hard to predict how the market for autonomous and remote-controlled vessels will evolve over the next five years. All the interview subjects believed that autonomous technology will be implemented to some degree in the future. This means that those companies that engage themselves in the commencing phase of autonomous technology in vessels, could get the edge.

Foreship is a well-established company in the shipping business. The uncertainty that surrounds the implementation of autonomous technology, leads to a careful approach by companies. Investing a lot of time, money and effort into something that may or may not be the next technological evolution in the shipping business, could be a great risk. But the risk might be worth taking. Foreship should at least prepare for the possibility that autonomous technologies are coming and that it may be here to stay. The autonomous testing projects of the ferries Falco and Folgefonn proved that complete autonomy is possible to achieve. The question is if the benefits outweigh the downsides.

There are several business opportunities regarding autonomous and remote-controlled vessels. Looking at the current state of autonomous technology and the interview results, I will assess the most viable business opportunity for Foreship as of this moment. My suggestion is presented below.

Consulting. This seems to be the best and most relevant business opportunity for Foreship as of today. Foreship already do a lot of consulting work, and knowledge about autonomous technology in vessels would be a great addition. This would require extensive research about legislation, technology, cost-effectiveness and most importantly feasibility. This would mainly be for shipowners wanting to invest in autonomous technology. Foreship could guide the costumer and help with the regulatory work to assess the situation and help with understanding what the limits are, technologically and legally. Foreship could also evaluate the cost-effectiveness about what is worth doing and what would be redundant regarding costs and safety. This proposition would not require a big investment and the risks are basically non-existent. Therefore, I see this as the most viable business opportunity regarding autonomous vessels and remote-controlled vessels for Foreship.

9 Discussion

I did not know much about autonomous and remote-controlled vessels when I chose this topic. I knew about the concept of autonomy and it seemed really interesting to me. It was quite difficult for me to write about this because of that reason and also because the technology has not been implemented yet. The concept of autonomous and remote-controlled vessels is a broad subject. One could delve deep into all the different aspects, but I chose to focus more on only getting the essential information about each important aspect. There are so many uncertainties regarding these vessels, and no one knows what the future holds.

9.1 Result discussion

As the future is so uncertain, it was challenging to establish a clear understanding of the upcoming implementation of autonomous technology. There are so many questions that remains, without a clear answer. How are we going to do with the legislation? Is it possible to develop an AI that is smart enough to replace humans completely? To what degree is it possible to implement autonomy? Is it even worth implementing? What about cybersecurity? The answers to all these questions lie in the future.

I think personally that a lot depends on the success, or failure of Yara Birkeland. If it turns out to be a great success, more companies want to invest money and effort into developing autonomous and remote-controlled vessels. The interest would definitely increase, and we might see more autonomous vessels sooner rather than later. However, if it turns out to be failure, it would probably discourage companies from investing and thus slowing down the development even more. One thing is clear, there is a need for autonomous technology, as it would make seafaring safer and more efficient. I think we will see autonomous technology be implemented to some degree in all the modern vessels, in the future.

Because there are so many questions lacking an answer, I concluded that the most viable business opportunity would be consulting. It is a good way of gaining knowledge about autonomous and remote-controlled vessels for the future. It could be a good base for a potential new department in the company when autonomous technologies are more common. My idea is that it could lead to a programming department that would develop autonomous AI systems for vessels. This would however probably require a big investment and it would be a great risk, certainly when things are so uncertain today. Therefore, I do not see this as a viable business opportunity at this moment. Maybe in the future when autonomous and remote-controlled vessels are a regular sight on the seas.

9.2 Further research

Further research is needed to delve deeper into all the important aspects and to get a better understanding of everything. I would recommend reading DNV GL's guide in detail as it is quite comprehensive. In the next few years things will change, regarding autonomous and remote-controlled vessels. The autonomous technology and the legislation will develop every year and it is important to monitor the changes to stay up to date. This is important as new opportunities can arise at any moment as the new autonomous technologies develops.

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