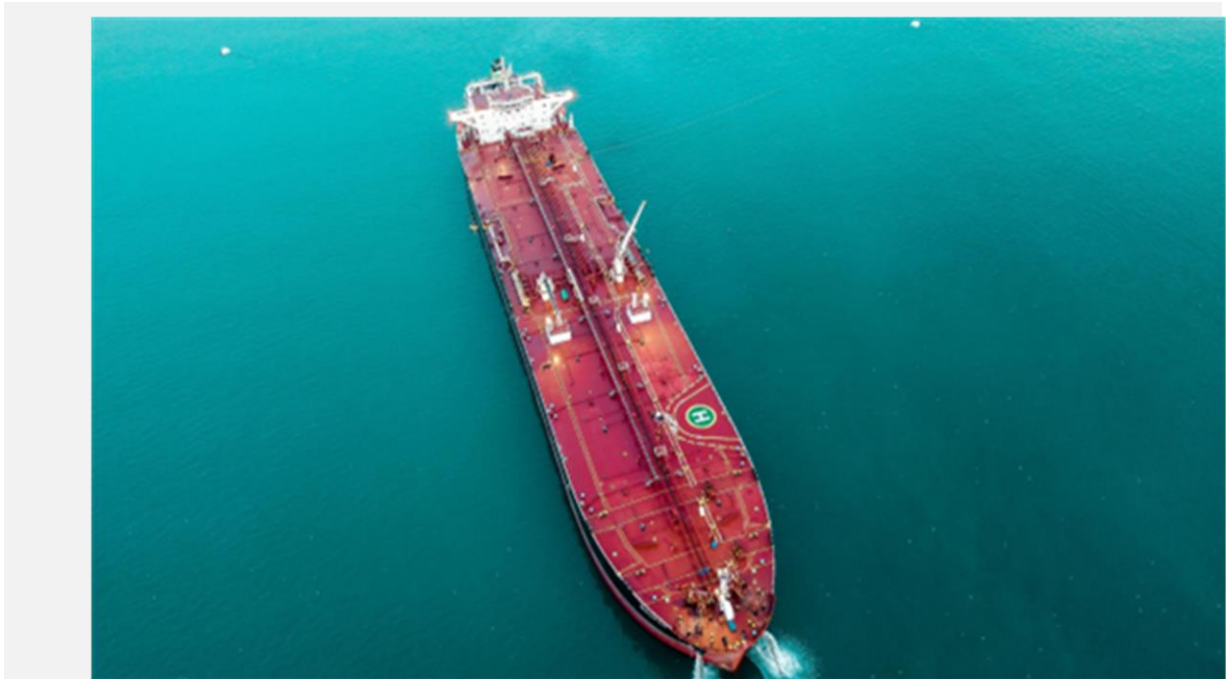




CHALMERS



Maritime Autonomous Surface Ship

Bachelor thesis for Marine Engineering Program

JONATHAN NIELSEN
THOMMY DAHLQVIST

DEPARTMENT OF MECHANICS AND MARITIME SCIENCES

CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden, 2022

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JONATHAN NIELSEN
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JONATHAN NIELSEN
THOMMY DAHLQVIST

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Department of Mechanics and Maritime Sciences
Chalmers University of Technology
SE-412 96 Göteborg
Sweden
Telephone: + 46 (0)31-772 1000

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Department of Mechanics and Maritime Sciences
Chalmers University of Technology
Gothenburg, Sweden 2023

PREFACE

The authors would like to thank all off the companies that took their time to answer the survey. We would Also like to thank the teachers and librarians at Chalmers university of Gothenburg for help with information, knowledge, language, layout and gave us the right tools to write this thesis. The authors would also like to thank Mr. Glenn Travis for the permission to use his photo of prism carrier. Finally, we especially thank our supervisor for taking his time and help us with good thoughts and feedback during the course of this project.

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SAMMANDRAG

Denna uppsats fokuserar på vad fartygsindustrin anser vara huvudproblemet med att gå från traditionellt styrda fartyg med en besättning ombord till hel autonoma när det kommer till dom tekniska frågorna, samt vilka av dom här områdena dom arbetar med idag.

Denna rapport kommer därför inte att gå in på djupet på vissa av problemområdena som berör autonoma fartyg så som den etiska faktorn berörande ombord-personal och dom ekonomiska faktorerna då dessa inte faller under målet med den här rapporten och kommer därför bara att nämnas som kortast.

Denna studien undersöker även om rederierna har någon större tilltro till tekniken i form av att dom kan tänka sig att använda sig av den i framtiden. Resultatet av detta har visat sig att det finns ett intresse för teknologin men att förtroendet för den är bristande medan teknikbolagen verkar se ljuset på framtiden för den i all typ av sjöfart.

Nyckelord: Helautonom, Teknologitvecklare, Rederier

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THOMMY DAHLQVIST

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Chalmers University of Technology

ABSTRACT

This report is focused on what the shipping industry consider to be the main problem areas with going from a traditional shipping vessel with a crew working onboard into a fully autonomous one when it comes to the technical aspects, and which of these areas they are working on today.

This report will therefore not go into detail regarding some of the problem areas with autonomous vessels like the ethical factors considered with onboard personnel and the economical factor as these areas does not fall under the purpose of the thesis, they will only be mentioned in short.

Another question that was desired to get an answer to is if the shipping industry have any faith in the technology in terms of if they can see that they will be using it the future. The result of this shows that the shipping industry seem to have a keen interest for the technology that is coming but does not see a future for it in their brand of shipping.

Keywords: Fully autonomous, Technology companies, Shipping industry

TABLE OF CONTENTS

TABLE OF CONTENTS	iv
1 Introduction.....	1
1.1 Aim of the study	1
1.2 Research questions	1
1.3 Delimitations	1
2 Theory	2
2.1 Autonomy at sea.....	2
2.2 Legislation and classification.....	2
2.3 Communication	3
2.4 Education.....	4
2.5 Maintenance & reliability.....	4
2.6 Technology on the market today and future challenges.....	5
3 Methods.....	7
4 Results.....	9
4.1 What problem areas does the shipping industry consider to be the main issue with autonomous vessels today?	9
4.2 Does the shipping industry see a future for autonomous vessels?	10
4.3 What areas are the technology companies working on today?	12
5 Discussion	13
5.1 What problem areas does the shipping industry consider to be the main issue with autonomous vessels today?	13
5.2 Does the shipping industry see a future for autonomous vessels?	13
5.3 What areas are the technology companies working on today?	14
5.4 Method discussion.....	14
5.5 Reliability and Validity	15
6 Conclusion	16
6.1 Recommendations for further research	16
References	18
Appendix 1	20

LIST OF FIGURERS

Figure 1.1 Picture: Prism Carrier.....6

Figure 1.2 Diagram: Current employment9

Figure 1.3 Diagram: Main issue10

Figure 1.4 Diagram: Completely autonomous in the future11

Figure 1.5 Diagram: Interest of making their vessels more autonomous.....11

Figure 1.6 Diagram: Currently working on.....12

LIST OF TABLES

Tabell 1 Beskrivning av tabellinnehåll..... **Error! Bookmark not defined.**

ACRONYMS AND TERMINOLOGY

AI	Artificial intelligence
GT	Gross tonnage: total of ships overall volume.
IMO	International maritime organization: The IMO sorts under the United Nations and constitutes an international maritime authority.
MASS	Maritime Autonomous Surface Ship.
CEO	Chief Executive Officer.

1 INTRODUCTION

Technology is ever going forward and the technology for the shipping industry is no exception to this. But as with most new technology there are problem areas that need to be worked out before they can be fully implemented and marketed. Eriksson & Gevriye, (2018) describes the main problems today with making a vessel completely autonomous is internet connectivity, the transition phase, law delegations, cyber security, piracy treats and the ethical considerations that needs to be addressed as well. There is also major differences on an organizational level of having a autonomous fleet compared to a manned one Aiello et al. (2020) but as said before new technology is still coming even for the shipping industry.

So, all the while fully autonomous ships seem like a near certainty in the future with some vessels already being built and tested like Yara Birkeland (Yara, 2023). It seems quite clear that the technology companies seem to think that they have these problem areas covered. The question is what the shipping industry considers to be the main problem areas to be focused on as of today and if they see a future for autonomous shipping, and what areas they are working on today

1.1 Aim of the study

The aim of this report is to see what the shipping industry identifies to be the main problem areas with the concept of autonomous vessels as of date. The study will also focus on if the shipping companies see a future where their vessels will be fully autonomous and what areas the technology companies are working on today.

1.2 Research questions

1. What problem areas does the shipping industry consider to be the main issue with autonomous vessels today?
2. Does the shipping industry see a future for autonomous vessels?
3. What areas are the shipping industry working on today?

1.3 Delimitations

This study will neither go into the financial aspect of autonomous shipping nor will it go into the social or ethical aspects of autonomous shipping.

The study has been limited to the technical aspect of the area and what the developers of the technologies and the shipping companies considers to be the current problem areas of the technology developed for autonomous shipping going forward.

2 THEORY

2.1 Autonomy at sea

Autonomous vessels or more specifically in this case Maritime Autonomous Surface Ships henceforth referred to as MASS are ships that to a varying degree can perform tasks independently of a crew (IMO, 2018). As Felski & Zwolak, (2020) concludes, autonomy at sea is going up in ratio compared to manned vessels from both the research and a market side of the maritime community (Felski & Zwolak, 2020). As this is a somewhat new industry the framework for how this industry should operate and develop is still in it's early stages with new regulations and frameworks being laid down and new technology being developed all over the world the industry is in need of a solid internationally laid legislation on how to operate and how to classify their products.

2.2 Legislation and classification.

The international Maritime Organization has started their work on a legislative framework for MASS vessels that in it's early stages will be a non-mandatory code that will be adopted by the year 2024 which will then transition into a mandatory code by 2028 IMO, (2022). So as for the moment the market for MASS vessels stands without a clear international legislative framework on which to operate. While the legislative framework is on the way, IMO has set up a framework to different levels of autonomy in general for MASS vessels in different degrees.

Degree one: Ship with automated processes and decision support: seafarers are onboard 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 two: Remotely controlled ship with seafarers onboard: the ships is controlled and operated from another location. Seafarers are available onboard to take control and operate the shipboard system and functions.

Degree three: Remotely controlled ship without seafarer on board: The ship is controlled and operated from another location. There are no seafarers on board.

Degree four: Fully autonomous ship: The operating system of the ship is able to make decisions and determine actions by itself (IMO, 2018).

The classification societies have come a bit further in their work on autonomous vessels. Det Norske Veritas (DNV) has published a set of guidelines on how to classify a MASS vessel. In their guidelines they have put up a framework for how to classify the different levels of autonomy for different functions like the level of autonomy for navigational functions is.

M – Manually operated function.

DS – system decision supported function

DSE – system decision supported function with conditional system execution capabilities (human in the loop, required acknowledgement by human before execution).

SC – self controlled function (the system will execute the operation, but the human is able to override the action.)

A – Autonomous function (the system will execute the function, normally without the possibility for a human to intervene on the function level.) (DNV AS, 2021).

Of course, other classifications societies have put up a framework to help guide the development of autonomous technology like Bureau Veritas (BV) came with theirs in 2017 and revised it in 2019 (BV, 2019).

Before IMO published their classification of four degrees of autonomy Lloyd’s register, (2017) published a different classification levels than that of IMO with six levels instead of four as listed.

AL 0) Manual: No autonomous function. All action and decision-making performed manually (n.b. systems may have level of autonomy, with Human in/ on the loop.), i.e. human controls all actions.

AL 1) On-board Decision Support: All actions taken by human Operator, but decision support tool can present options or otherwise influence the actions chosen. Data is provided by systems on board.

AL 2) On &Off-board Decision Support: All actions taken by human Operator, but 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 give human Operators the opportunity to intercede and over-ride.

AL 5) Fully autonomous: Rarely supervised operation where decisions are entirely made and actioned by the system.

AL 6) Fully autonomous: Unsupervised operation where decisions are entirely made and actioned by the system during the mission (Lloyd’s register, 2017).

As the work for international regulations is ongoing there is few to no regulations on state level. As for the Swedish transport agency, say that autonomous and ships have no special regulations for them and that they need to comply with the same regulations as traditional vessels (Transportstyrelsen, 2022).

2.3 Communication

With the different levels of autonomy comes different levels of need for communication both internally and externally. For autonomous vessels of degree two, three and four a stable internet connection is of outmost importance as the vessels for degree two and three require a human for the navigation from a remote-controlled station, although be it that the crew onboard for a degree two vessel can take over the navigation onboard should the vessel loose connection.

Multiple highspeed satellite connection options are on the rise for this such as starlink that currently offers a 220 mbps connection speed on most oceans already and are still expanding their range (*Starlink Maritim, 2023*). But even with a stable high speed internet connection a stable local network onboard is of outmost importance as well as there is multiple systems onboard that is “speaking” to each other in order for the vessel to be able to make decisions on it’s own. For example, all autonomous ships will require a collision avoidance system which need to be able to control the speed and the direction of the ship so Revolutions per minute (RPM), pitch and rudder combined with sensory systems for calculating path’s and to sense obstacles like the Automatic Identification system (AIS) and radar systems. There is a number of systems being tested but as Pietrzykowski et al., (2022) says “An analysis showed that no comprehensive solutions exist for autonomous navigation systems in sea-going ships. “In this article when they are presenting their solution to a system with drones for extra information gathering, there is still much left in the field to be done (Pietrzykowski et al., 2022).

As with everything connected to the internet there is always the risk of hacking to consider as well when developing products to this market and how to deal with that risk. Models to identify and prevent cyber security risks are also being developed like Bolbot et al., (2020) who identified a number of risks using their method on the autonomous vessel they investigated. For some examples on the shore control centre of the vessel and on the ship control station and stated that one measure that could be taken to increase the security was to eliminate internet communication links (Bolbot et al., 2020).

2.4 Education

Working with autonomous ship will require a new way of thinking from ship management to government and to educators. For educating instances the educational programs need to follow the development of autonomous shipping carefully and develop programs that is catering better to this new market as it will require a entirely new skillset as an autonomous fleet.

It will require seafarers to have a wider skillset towards IT as both the ships and harbours would become more digitalised as concluded by (Baum-Talmor & Kitada, 2022). There is also Lee et al., (2019 p.732) that states “domestic designated education institutions need to revise their education policies to assist existing navigation technologies by applying convergence technology based on the fourth industrial revolution rather than conventional navigation and institutional management technology.” So not only does the educators need to shift to a more IT oriented approach to shipping a mixed educational approach between the nautical and engineering sides might be needed as well. The shipping companies as a whole needs to make major revisions on how they operate should they wish to switch to autonomous shipping(Aiello et al., 2020).

2.5 Maintenance & reliability

There is a lot of papers regarding the navigational systems, the economical factors and the ethical questions that arise when it comes to autonomous shipping but very little is so far written about the maintenance and reliability side of it. Karatuž et al., (2022) have come up with a model on which to determine what type of maintenance model that is best suited to which degree of autonomy. For example, if you going to use a corrective or a predictive style as well as some improvement of three maintenance types in order to make them more applicable to MASS vessels. In short, they present six different maintenance alternatives. Three “Single way” alternatives and three hybrid alternatives as listed below.

Alternative 1: alone implementation of correction maintenance (CM)
Alternative 2: alone implementation of Time-based maintenance (TBM)
Alternative 3: alone implementation of Condition-based maintenance (CBM)
Alternative 4: implementation of CBM + CM in a hybrid way
Alternative 5: implementation of CBM + TBM in a hybrid way
Alternative 6; implementation of CBM + CM + TBM in a hybrid way
(Karatuđ et al., 2022).

Correction or corrective maintenance is a form of maintenance method where you work is based actions taken when a problem has occurred for example like a bearing breakdown in a pump, you identify the problem and correct it.

Time-based maintenance is like the name suggest a maintenance method based on time in this method you schedule your performance for example after 2000 running hour on a pump you schedule to check the filter, and after those 2000 running hours has been done you perform the work. Condition-based maintenance is a maintenance method based on predictive form of maintenance an example of condition-based maintenance would be if for example an engineer reads a pressure of a fuel pump over the course of some time and finds that the pressure is decreasing and then act to correct the problem based from the condition it is in.

2.6 Technology on the market today and future challenges

2.6.1 Autonomous ships

Some ships with the purpose of getting to the point being fully autonomous is already being tested on the market today, the vessel Yara Birkeland is currently in commercial operation in Norway (Kongsberg, n.d.). Yara is currently operating with a crew onboard and with a detachable bridge, the route planning, condition monitoring operational monitoring, decision support, surveillance of the ship and its surroundings is of today planned in a remotely operated control station (ROC) at Massterly in Horten (Kongsberg, n.d.). So, the vessel is not fully autonomous yet but will gradually convert to full autonomy over the coming years, while in operation (Yara, 2023). Some ships that can be classified as semi-autonomous like the liquid natural gas (LNG) carrier Prism Courage (shown below in figure 1.1) that completed the world's first oceanic crossing using autonomous navigation delivered by Hyundai heavy industries subsidiary Avikus technology (safety4sea, 2022). Rolls Royce marine which today is a subsidiary to Kongsberg published in 2016 that they envisioned a fully autonomous oceanic going vessel by the year 2035 (Rolls Royce, 2016).

Figure 1.1 Prism Courage



The ship Prism courage photo taken by ©Glenn Travis. Permission to use the picture has been given by Mr.Gleen Travis the copyright holder.

2.6.2. Artificial intelligence (AI)

AI is one technology of major interest to shipping companies today (Ichimura et al., 2022). AI is also big component needed for vessels that aim for autonomy as AI is used in a variety of ways like collision avoidance and decision support (Burmeister & Constapel, 2021). One of the big advantages to make the shift from a traditional vessel with a crew onboard to an autonomous one is to remove the risk of human error (Eriksson & Gevriye, 2018). Some estimations estimate that the human factor is the cause for as much as 80-85% in maritime accidents (Baker & McCarfferty, 2005), but even with this high number “It is expected that most autonomous ship systems will operate with continuous supervision from an RCC.” - (Rødseth et al., 2022) instead of the AI taking over the process of decision-making completely.

2.6.3 Ports

As ships is heading in the way to more autonomy so needs the harbours. “Autonomous sailing is not limited to moving the vessel safely through the seas, but it also includes docking the vessel. Docking is considered a difficult and critical manoeuvre in autonomous sailing.” - (De Kruif, 2022). The European union has started a project named ARGUS where parts of it’s aim is to develop automated cargo handling and autonomous shipping (EU, 2020).

3 METHODS

This study is based on a questionnaire survey and document research to grasp the subject. According to Denscombe, (2017) surveys is a good and reliable source for a thesis such as this where personal contact to collect all the data is not possible. Surveys is often used in thesis where a wide coverage is suitable. It is also a way to get clear figures and framework for a subject instead of getting a thousand different answers that in the end will be hard to summarize. It was chosen for this particular study as it was felt the most sufficient method to both reach out and to collect the material needed from the recipients as they are spread out throughout the world and an efficient method for collecting data.

3.1 Document research

To get a grasp on the subject, research was done by reading different thesis on the subject. The documents were found by typing autonomous vessels, AI, autonomous ships and autonomous shipping on google scholar, Elsevier and Chalmers library of earlier student thesis to see how this subject has been mentioned before. Many of the studies were aiming on other subjects around the whole situations. Economical, structural, logistical, and practical factors were often subjects that could be found in their studies. The documents that were found had all different approach on the subject and had different layout and were impartial. This gave a better view on the subject instead of using technology companies' sights and shipping companies that often use their inventions as marketing for their own value. The researchers were located all around the world so there was no connection between them which also gave more reliability.

Key phrases: Autonomous vessels, Ai, Autonomous ships, Autonomous shipping.

3.2 Recipients

The recipient of the survey needed to either be a shipping company or a technology company working with developing technology marketed towards the shipping industry to be relevant. With that in mind to get in touch with recipients relevant to the field the contact list for shipping companies at Sjöfartens Utbildnings Institut (SUI) for students that need to make contact with their respective company before their internship were used as a starting point. From there further recipients had to be contacted from the technology developers' side, after some search on autonomy the autonomous ship symposium were found and contact were made through email from their contact list of companies that were to showcase their company there.

3.3 Survey and it's result.

The survey was formed with a few predetermined answers from which the recipient could answer, this was done in order to narrow down the answering field to get a clearer result on the data received. Recipients only had to state if they were either employed or owned a shipping company or a technology company so that it could be determined how many of each side that answered while the recipient stayed anonymous and if the recipient choose, they could skip questions should they wish to do so. All recipients were reached by email to a total number of 31 out of those 8 answered the survey. The answers that were given on the research questions were already compiled in the web-based portal that were used. This gave a direct summary on the results that were given. These results were later put together in graphs that are presented in

this survey. The results were also analysed and based on the theory that were gathered around the subject. After that a conclusion could be made.

3.4 Ethics.

The participant of the survey is completely anonymous, the participants never had to state their name or the company they either worked for or owned. Both authors had no prior connections to the companies that were contacted for participation in the survey nor were in contact with said companies in any other interest or purpose than for this thesis.

4 RESULTS

To begin the recipient were asked if they were either employed or owned a shipping company or a technology company. Following this the survey did not continue in the same order as the research question but answer them all the same.

Question: Please select your current type of employment

The survey started with a question regarding what type of employment the reader of the survey was currently under. Four were currently employed by or owned a technology company and four being employed by or owned a shipping company resulting in a fifty, fifty answering field as can be seen in figure 1.2. The survey was sent to the CEO of the respective shipping companies or was to be directed to the CEO to answer. For the technology companies it was to be answered either by the CEO or the person in charge or development.

Figure 1.2



Figure 1.2. shows if the one answering the survey type of employment and number of answers given to the question.

4.1 What problem areas does the shipping industry consider to be the main issue with autonomous vessels today?

To answer this question the following question were asked.

Question: Which of the following options do you consider to be the main issue with autonomous vessels today?

The survey then continued to ask the reader in form of a couple of predetermined options what they consider to be the main issue with autonomous vessels today. Here four answered that they consider internet connectivity/safety to be the main issue, two maintenance reliability, one regulation and one said that none of the issues that we had preset for the questions aligned with that they consider to be the main issue. No one selected Ethical questions regarding onboard personnel. As shown in figure 1.3 this resulted in 50% internet Connectivity/safety, 25% Maintenance Reliability, 12.5% regulations, 12,5% None of the above and 0% on Ethical questions regarding onboard personnel out of a total of 8 answers.

Figure 1.3

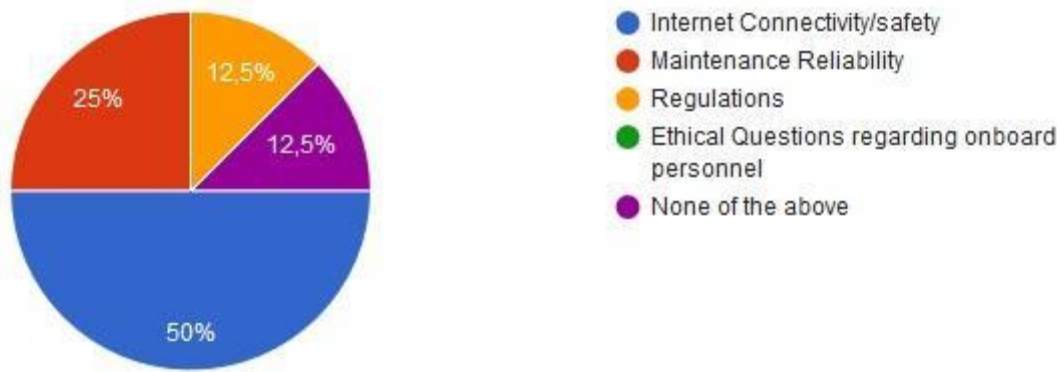


Figure 1.3 shows what the one answering the survey believes to be the main problem areas with autonomous vessels today relating to research question 1.

4.2 Does the shipping industry see a future for autonomous vessels?

To answer this question the following question were asked.

Question: Do you believe that the fleet will be completely autonomous in the future?

The survey then continued to ask if the reader believed that fleet would be completely autonomous in the future where six answered that they do not believe that it will and two answered that they think it will be. Resulting in 75% in belief that it will and 25% that were not as shown in figure 1.4.

Figure 1.4

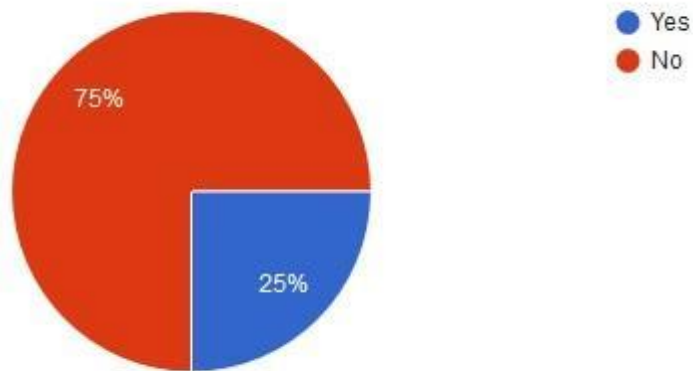


Figure 1.4 shows if the one answering the survey believes if their fleet will be completely autonomous in the future or not relating to research question 2.

Question: Does your company have any interest to make your vessels more autonomous?

In continuance with the previous questions, we asked if the reader had any interest into making their vessels more autonomous to which five answered that they had an interest in doing so and two answered that no such interest was held as shown in figure 1.5. Resulting in 71.4% that had an interest, 28.6% that did not hold that interest and one participant that opted not to answer the question.

Figure 1.5

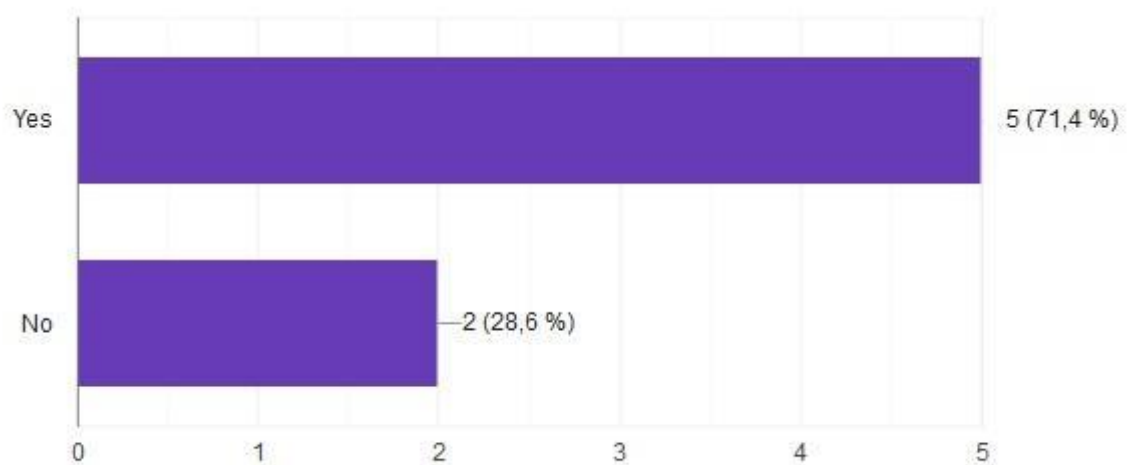


Figure 1.5 shows if the one answering the survey had any interest in making their fleet more autonomous also relating to research question 2.

4.3 What areas are the technology companies working on today?

To answer this question the following question were asked.

Question: If any which of the following options are you currently working on today?

The next questions were in which of these issues they were currently working on if any to which three answered that they are currently working on the internet connectivity/safety issue, three maintenance reliability, three is working on regulations and two said that they are not working on any of the previous mentioned issues. As shown in figure 1.6 this resulted in that 42.9% worked on internet connectivity/safety issue, 42.9% maintenance reliability, 42.9% regulations 28.6% none of the previously mentioned issues.

Note that in both the question for what they considered to be the main issue with autonomous vessels today and to the question of to what issue they are working with today the reader could select multiple points and in both question the ethical questions regarding onboard personnel could be selected but the survey got no one selecting this option. In total seven people answered this question out of a total of eight that participated in the survey.

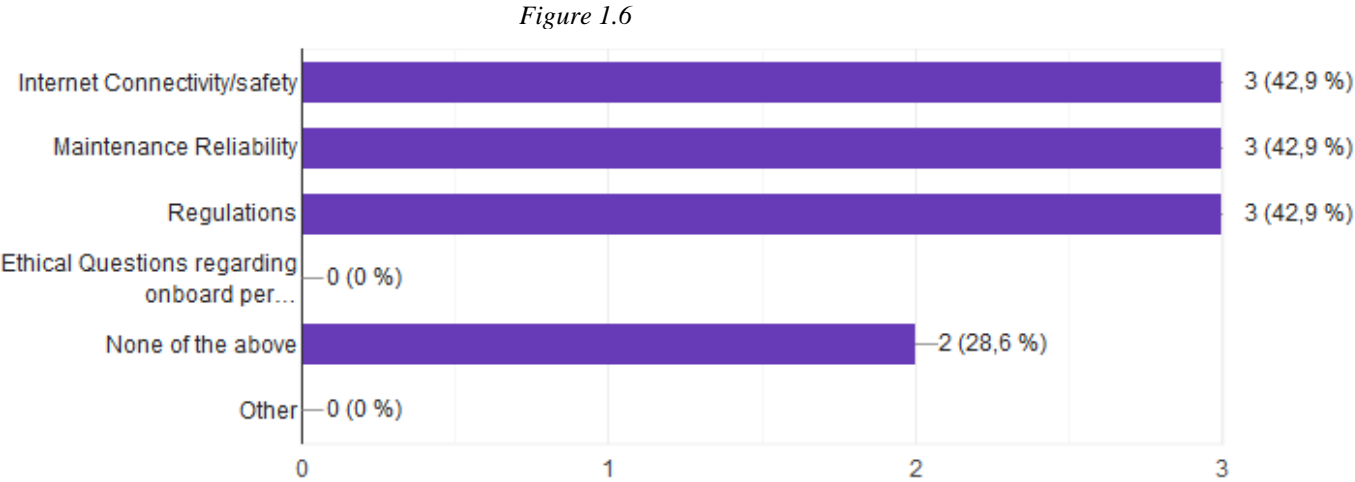


Figure 1.6 shows what problem areas the participants is working on today relating to research question 3.

5 DISCUSSION

The questions that were asked in this thesis are hard to get an answer to and are hard to predict. But by raising these questions to the companies the hopes were that it will put a little pressure on them since it is mainly in their hands if we will see an autonomous fleet in the future.

The questions were a bit open and could be more specific, which could have been done a bit differently. But the results were interesting and yielded a few answers that were not predictable, like the fact that none thought that the ethical question regarding onboard personnel were to be considered a main issue.

5.1 What problem areas does the shipping industry consider to be the main issue with autonomous vessels today?

Internet connectivity and maintenance reliability seems to be what the industry at large considers to be the main issues, with internet connectivity and safety being number one. The survey in retrospect could have been better specified in order to get clearer results. While the result clearly shows that internet connectivity and safety is the main issue the result does not really reflect if it's the connectivity aspect or the safety of the internet aspect that the shipping companies and the technology companies considers to be the issue or both.

As seen in the Theory part the autonomous fleet have obstacles among the way with communication, ethical factors and maintenance.

Connection is a big issue to the maritime market. As said in the article written by Pietrzykowski et al., (2022) the market is just in a pre-phase and more investments and a more reliable operative system is required to achieve an autonomous fleet. A fleet that is depending on the internet may be more reliable on its efficiency and its internal security. Regarding the maintenance on the vessel and its system, there is not many studies or tools how they are going to be operated. As Karatuž et al., (2022) mention there is an "alternative" solution on how it could be done but not any tested systems so far. More pilot systems need to be applied on the market and it also had to be operated for some time to be reliable.

Even if the fleet is developing the technology that is required, the ports still struggle with the progress of how they are going to adopt the new ships to their ports as said in De Kruif., (2022) article.

5.2 Does the shipping industry see a future for autonomous vessels?

Here only two out of eight said "yes" and the rest said "no". This result could be severely affected by how the question was asked. For example, it could be considered as the fleet in the company they are working on, the fleet of a country or the fleet of the entire world depending on who is answering the question and could therefore bring a very widespread result. Since it might be easier for most to picture their own fleet of vessels being autonomous than others fleet let alone the entire countries or the world leaving the result and the validity of the question to be questionable at best. With that in mind there is interest from the companies for autonomous vessels as could be seen from the result of survey question three, so while they have an interest for autonomous shipping there seems to be little faith for it to work in their own line of shipping. This corresponds well with other research such as

Ichimura et al. (2022) that also concluded that the established shipping companies do have an interest in the technology per say but does not see a future for a completely autonomous fleet in their companies. Another reason for the low answering degree on yes might be that the recipients consider the management reconstructions that needs to be done in order to go over to a completely autonomous fleet to be too severe or too big of a risk as of today. Another benefactor to this number might also be that in these questions four out of eight companies was technology companies and might not have any ships of their own and answered no because they simply don't have a fleet to be converted to autonomous shipping.

5.3 What areas are the technology companies working on today?

For what tech industry and shipping companies are working on versus what they consider to be the main problem areas it seems that they are working in the same fields with the exception of regulations. As very few considered this as a main problem area but a large number of the recipients are working within this field. This could indicate that they consider the area to be of importance but not an issue at large.

Yara Birkeland is now one of the first operating vessels on the autonomous market. It is still semi-autonomous operated since it has a crew onboard but is gradually converted to full autonomy. this shows that the market is progressing on this market and that there is an interest regarding autonomous vessels.

The AI development as said in Ichimura's., (2022) article is increasing and can be more applicable for the maritime market aswell. To erase the human factor that is in charge of 80-85% of the shipping accidents that is mentioned in Baker and McCarffertys., (2005) article, and more reliable shipping can be made by using AI.

5.4 Method discussion

For data gathering a survey with a web-based questionnaire complemented by articles was chosen as the method to go with this type of thesis. The way the questions were written was to give a quantitative point of view. This is because the research was based on the fact that the questions that were asked was what the shipping industry consider to be the main problem areas with going from a traditional shipping vessel with a crew working onboard into a fully autonomous one and if the shipping industry have any faith in the technology in terms of if they can see that they will be using it the future.

Considering the questions, this method was a good fit as an overall picture of what the market looked like was something that was asked rather than getting into the depth of the subject as an individual actor. The hopes were to get a greater response rate than what was the result. This resulted in the survey not getting the comprehensive picture that had been desired, but a trend in the questions could still be seen.

An attempt to get in touch with the actors who had responded and to carry out a more qualitative survey was attempted, but many of them lost interest there. One way of solving this would be to try to reach out to more companies and have a bigger time span.

When choosing which companies to send the survey to, the goal was to get as big variety as possible from the shipping side in terms of which trade they operate with. The technology

companies were selected with the premise that they are at the least to some extent actively working with technology intended for shipping. But even here with the low degree of answers received, the validity has become questionable.

5.5 Reliability and Validity

The reliability of the thesis is somewhat questionable. While the questions that were asked in the survey do indeed fill the point of what they were meant to answer they could have been written in a clearer way. For example, the question Do you believe that the fleet will be completely autonomous in the future? could have been re phrased to Do you believe that the fleet of your company will be completely autonomous in the future? The reliability of the data collected comes further into question regarding the low number of participants response rate considering how big the intended group for the survey could be (Denscombe, 2021). Another thing that could have been done in order to bring up the reliability would have been to have a open question section of the survey were the recipient could write their own answer instead of only having preselect able answers in the question were he recipients were asked what problem areas they consider to be the main issue for example.

Complementary research done on prior scientific documents to the survey that was made for this thesis brings an element of validity to the thesis above the fact that the survey participants were selected specifically for their relevance in the field of autonomous shipping. While the number of participants in the survey brings a somewhat small picture of what the thesis set out trying to answer it till manages to answer the research questions.

6 CONCLUSION

The results from the survey may as said be questionable due to the low number of companies answering it, this should also be considered if this thesis is to be used in further studies of the subject.

In regard to what the companies are working on it is pretty much clear that they have left no stone unturned in order to accomplish the goal of getting to the point where the vessel is completely autonomous without any onboard personnel, although with the mid-step of the ships at first being remote-controlled from an onshore station.

1 What problem areas does the shipping industry consider to be the main issue with autonomous vessels today?

Internet connectivity, regulations and maintenance reliability seems to be what the industry at large considers to be the main issues, with internet connectivity and safety being number one.

2.Does the shipping industry see a future for autonomous vessels?

As it seems from the survey the shipping industry's faith in the future for autonomous vessels is small but as stated before this could very well be due to how the question was put so no clear conclusion can or should be drawn from the result of this thesis. As seen in both the theoretical part and the survey the market may not be fully interested in full autonomous vessels but are interested in making more semi-autonomous vessels.

3.What areas are the technology companies working on today?

In regard to what the companies are working on it is pretty much clear that they have left no stone unturned in order to accomplish the goal of getting to the point where the vessel is completely autonomous without any onboard personnel, although with the mid-step of the ships at first being remote-controlled from an onshore station. as mentioned in the theory part there is several new projects on this area.

There are mentioned many new inventions on the field regarding software products but not as many vessels. AI as mentioned is one big part in making autonomous driven vessels to happen. To minimize the software faults ant to erase and achieve an 100% reliable shipping.

Even making maintenance programs that can be in hand for the new unattended ships and have ongoing maintenance will also be in need for the autonomous shipping to happen. To continue to develop basic programs and systematically tools and later adopt them will be the absolute start for the market.

Yara Birkeland is operating semi-autonomous and will sone be operated as a fully autonomous vessel. The ship prism courage is also a pioneer on the market by going ocean wide even if it is semi-autonomous. The market is developing even if it is too early to say if there will be full autonomous or semi-autonomous vessels.

6.1 Recommendations for further research

With the subject matter of this thesis being the development of technology and to see if it corresponds with that of what its intended markets think and need from it, the findings from this thesis will only be of relevance at best for a short while. So continued research will be necessary for future analysis.

Future research can focus on a smaller area of this subject to get a more accurate answer. Therefore it would be interesting to see if more distinct markets would see a future with autonomous vessels, such as passenger ships on longer routes and ocean-going vessels? It would also be interesting to get more companies involved and take part in this question for further researches.

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APPENDIX 1

Appendix survey questionnaire

Please select your current type of employment:

- Currently owner or employed by a technology company
- Currently owner or employed by a shipping company

Do you believe that the fleet will be completely autonomous in the future?

- Yes
- No

Does your company have any interest to make your vessels more autonomous?

- Yes
- No

Which of the following options do you consider to be the main issue with autonomous vessels today?

- Internet connectivity/safety
- Maintenance Reliability
- Regulations
- Ethical questions regarding onboard personnel
- None of the above

If any which of the following options are you currently working on today?

- Internet connectivity/safety
- Maintenance Reliability
- Regulations
- Ethical questions regarding onboard Personnel
- None of the above
- Other

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