University of South-Eastern Norway

Digital transformation in the maritime industry

The increasing implementation of autonomy and need for competence reskilling.

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Abstract

Today's ongoing development of technology shows promising impact on the maritime industry. The use of technological tools is growing, and new developments are continuously ready to take over tasks that are done by humans today. In the maritime industry, there is an increasing focus on digital solutions and autonomous vessels that facilitate labor previously done by workers on ships. This technology shows good prospects for maritime jobs and operations, which could ensure more efficient shipping and ease of chores for the workers.

Although we see such a positive development in the future, it raises a concern about whether we are equipped enough to cope with the upheaval that technology brings. Could there for example be a change in competence requirements to operate these autonomous vessels, that we are not prepared for? The digitalization raises a concern regarding what skills future employees will need to adapt to in order to operate alongside the technology. A consequence of modernization could be a greater focus on for example IT than navigation in schools and workplaces. This would ultimately lead to a need for reskilling the maritime employee.

Dramatically transforming the work tasks sometimes leads to a loss of tacit knowledge in an organization and therefore reskilling could be important for the future maritime industry. With such a change in focus and practice, one should consider which challenges could arise. The world is changing, but is the industry tagging along? It is possible that this focus shift will reveal tasks that cannot be replaced by machines and autonomous systems, but rather bring awareness on work tasks and safety routines that will require people to do the work themselves, physically present. Today a lot of the focus is on what technology and autonomy can provide us and how it can relieve humans from work. While this thesis will explore the subject from a different perspective, rather looking at which areas humans are not so replaceable by technology, and the importance of a human-technology balance and reskilling.

The need for continuous implementation and adaptation is very important, meaning looking at what types of competencies and needs are going to be required in the future to benefit the most from this digital and autonomous transformation. Highlighting the need for also adapting and changing competence according to the technology, could provide better usage and understanding of the tools implemented. It could also help the maritime industry gain more strategic knowledge and a bigger competitive advantage in their segment.

The method used in this thesis is quantitative data collection, in the form of a distributed questionnaire. Information has also been collected from relevant articles to increase knowledge and insight on the subject in a literature review. Combining these two methods the thesis is based on previous quality studies and research, and current opinions from key persons in the maritime segment. The results gathered from the questionnaire shed light on various opinions on digitalization in the maritime industry, both optimistic and critical. This was considered valuable information that confirmed a skepticism toward increased technology and also a need for reskilling maritime workers.

Keywords: *Digitalization, readiness, competence, future requirements, human-technology balance, autonomy, maritime technology, maritime industry and education.*

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I would like to give my sincere gratitude and thanks to my supervisor, Amit Sharma, for taking the time to guide me and motivate me while writing this thesis. Digital readiness in the maritime industry is a subject I find genuinely interesting and I always had support from my supervisor along the way. He allowed me to explore this area and to angle the master thesis the way I wanted, with guidance and help. Thanks to his knowledge and support I was able to execute and deliver the thesis as I wished.

I would also like to thank every participant in the questionnaire that took their time to give answers and provided valuable insight into my thesis. This was considered a necessity for the thesis, in order to provide realistic suggestions for the digital development in the maritime industry.

Also, a special thanks to my family and friends that have supported me along the way while taking my master's degree.

Tonje Erdal
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Introduction

In a consistently more digitalized day-to-day life, technological and autonomous developments spark promising aspects for the future. The tools for easing our lives are becoming more advanced and being integrated into every possible aspect. Sometimes there are technological tools for us to buy and use, without us even knowing we needed them in the first place. In this development, one can wonder if technology decides over us to a greater extent than the other way around, and in that scenario it results in us adapting to technology. For the maritime industry, this is an important topic to indulge in. It could be essential for the maritime industry to reflect upon what changes digitalization brings, in order to hopefully better ensure stable maritime transportation, operation and business. The technological changes could influence for example ship structures, operations, work tasks, and educational backgrounds in universities (Gibbs & Bazylik, 2022). Some advantages of digitalization are that it could be cost-effective, environmentally friendly, and relieve a lot of time-consuming tasks for humans (Praetorius, Hult, & Sandberg, 2020). The aim of this study is to evaluate the digital readiness of the Norwegian maritime sector, hoping to uncover which areas are most and least exposed to this change, with a particular focus on autonomy and competence.

Autonomy is a digital development that could be implemented in ships to ensure a competitive advantage in the future of maritime transport. It comes in different degrees and levels, and as of now, there are predictions and developments for fully autonomous ships that make their own decision and planning based on programming and learning. The level of autonomy will allow humans to interfere if for example something goes wrong or if the decisions made by technology do not seem to fit the scenario. The developments are happening, as mentioned, because autonomy could lead to more efficient maritime operations with sustainability and safety measures (MUNIN, 2016). Norway has been leading in the development of autonomous ships for the past few years, but the digital transformation is happening at a great speed worldwide (Halvorsen, Sørensen, & Hovstein, 2020). Autonomy does however raise a concern about whether or not we are prepared for the issues that could arise when adapting to technology and reskilling maritime workers for the future.

The technology shows promising outlooks not only for the efficiency and matters of logistics but also for freeing humans from work tasks at sea, such as machinists, operators and navigators (Gibbs & Bazylik, 2022). Although this digital development era looks mostly optimistic regarding new autonomous operations, there are important aspects of adjusting to the technological tools and new methods of doing things. By considering what competence, work tasks and educational aspects will be changed in the future, one could better learn how to adjust to the technology and ultimately benefit from it more.

Therefore, it would be feasible to first evaluate and quantify preparedness to embrace digitalization in the maritime industry. This includes looking at which work tasks could be fully or partially replaced by the new technology, and which work tasks done by humans today should not be digitalized to such a great extent. Not only looking at how autonomy can benefit humans but how humans also can be an important element for the technology to function, will most likely induce a positive outcome. There is a possibility that humans are not able to meet autonomy in the necessary capacity which leads to technology exceeding us. In that scenario the outcome of efficiency is counterintuitive.

According to recent analyses, some weaknesses and threats to the human role towards autonomous shipping are competence demands and maintenance for future mariners (Praetorius, Hult, & Sandberg, 2020). That is why it is reasonable to explore whether future maritime jobs will have another set of competence requirements with for example a different work background to operate these vessels. There are however studies that state that maritime workers will be just as essential in operating future ships, but more as a supervisory controller. The question of where the ships will be operated from still stands (Endsley, 2017). Therefore, the reskilling of knowledge alongside digitalization could be key for future maritime jobs, both stationed at sea and on land.

When it comes to skills in education and workplaces in the future, there are areas that could change in terms of change management and maritime technology readiness. For example navigational skills, machinist, logistics and operation. This could influence focus in schools, maritime education and what workplaces look for when hiring. There are suggestions that future maritime operators could benefit from a higher degree of technical literacy, and that for example experience in computer gaming can be a bonus (Mallam, Nazir, Veie, & Sharma , 2019). The same study also emphasizes the need to work on traditional ships to understand ship design,

structure and operations. It raises an interesting concern on whether for example machinery will be as essential as data interpretation, computer science and analysis when operating advanced, digital vessels in the future.

Ultimately, the goal of this thesis is to uncover some important aspects of reskilling in a continuously more digitalized maritime industry, and how well it can go alongside the technological evolution we see happening. Hopefully, the thesis uncovers aspects of human maritime labor that digital tools and autonomy should not or cannot replace. The importance of evaluating the human role in this transformation could be just as essential because it could suggest how to better care for and educate humans for future maritime jobs.

Research question

Following the research question for this master thesis will be:

How can the maritime industry ensure a workforce with the necessary reskilled competencies to succeed in a digitalized future?

Scope

The thesis will primarily focus on competence and reskilling in the maritime industry in order to operate autonomous ships and develop alongside digitalization. The thesis will not go into detail on matters such as safety issues, technical requirements and logistics. It will also not go into a description of what work tasks are included in a profession such as a machinist or a navigator. Therefore some previous knowledge on the matter is an advantage.

This thesis is not an attempt to definitively decide whether or not modernization in the maritime industry is sustainable, but rather explore aspects affecting and preventing digitalization from going smoothly.

Thesis structure

The thesis has been structured with an introduction, research question and scope. It continues with the literature review to uncover relevant theories and research on the subject. The next chapter will be the methodology which explains what method is used to gather information and facts to explore the subject and research question further. Next is the results, displayed with self-made figures. The following part is the analysis and discussion, which will go further into the data collection and compare it to relevant literature. Then a conclusion is presented, which answers the research question, and provides some suggestions for further studies on the matter.

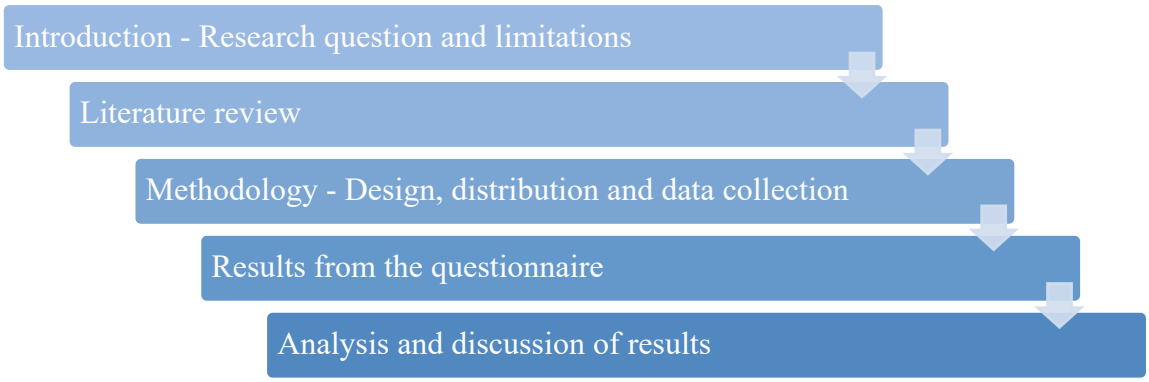


Figure 1 - Thesis structure.

Literature review

In order to explore this master thesis and answer the research question as best as possible, it was necessary to collect relevant existing literature on the subject. It was important that the information collected was current, and therefore this thesis is mostly based on recent articles. This creates a relevant theoretical basis for further explorations in the thesis.

The scientific articles were gathered from databases such as Scopus, ResearchGate and Google Scholar. The literature search was mostly conducted at the beginning of writing the master thesis, in order to gain ground knowledge on the matter. Although it has been an ongoing process to continuously gather relevant information on the subject. The search words to find these relevant articles have been *digitalization, maritime, industry, autonomy, competence, and future skills.* There has been an attempt in finding a variety of articles on the matter that not only confirm the positive outlooks of digitalization but rather explore the subject from different angles. In that way, one gains a more nuanced literature review. It has also been important to find articles with a high number of citations, in order to select articles of quality to be included.

The literature review presents the selected articles in four different chapters below. The chapters are Digitalization and autonomy onboard ships today, Opportunities and challenges with increased technology, Competence in schools and workplaces and lastly Reskilling maritime employees.

Digitalization and autonomy onboard ships today

There are several articles that confirm the increasing digitalization in the maritime domain. According to Vakil (2022), autonomous ships can be categorized as MASS, meaning Maritime Autonomous Surface Ships. The international maritime organization (IMO) has defined MASS and classified it into four different levels of automation (Vakil, 2022). The levels range from some autonomous functions on board a ship with various human interactions to fully autonomous operations without the presence of crew or human interference. The four different levels are illustrated in Figure 2.

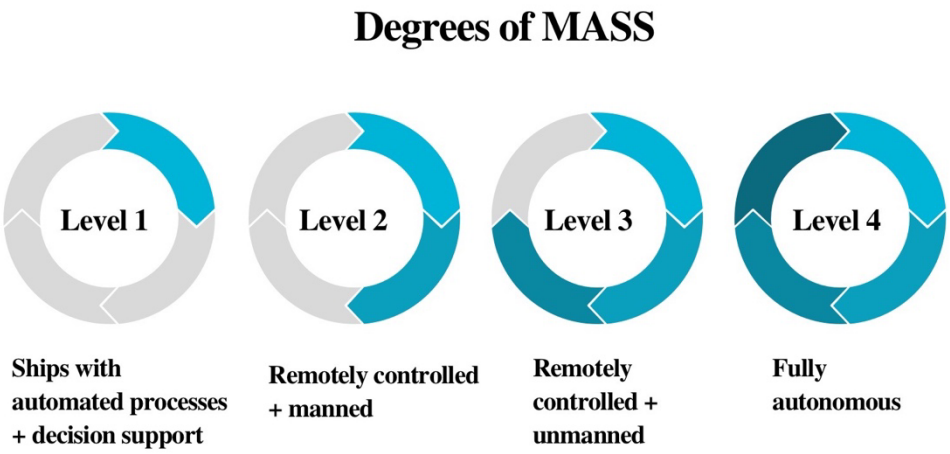


Figure 2 - Self-made illustration showing the different levels of autonomy, inspired by Kim et al. (2019), (Sharma & Kim, 2022).

As Figure 2 depicts, there is a complexity of technological combinations that can take place on a vessel and one can see that the definitions of autonomy on ships are already established. According to Broek, Griffioen and Drift (2020), autonomy cannot be defined as a completely categorized system because it fully depends on the levels of technology and software on the ship (Broek, Griffioen, & Drift, 2020). However, the different levels in Figure 2 could help explain to what degree autonomy is in charge of operating the ship and whether or not humans are involved in the processes. Vakil (2022) concludes that autonomous ships compared to traditional ships must be met with a certain competence and expertise. One of the reasons is that there are different scenarios and happenings that can cause confusion of authority when operating autonomous ships (Vakil, 2022). Therefore, MASS practice will require reskilling and competence readiness.

Emad, Enshaei and Gosh (2022) state that autonomy is being applied in several segments and taking over our day-to-day life (Emad, Enshaei , & Ghosh, 2022). The growth in digitalization implies an interest in higher levels of autonomy in commercial ships and mass transportation. This causes a change in how work is performed and what tasks are done by whom. Today we can see the start of some early projects of fully autonomous vessels at sea. Yara Birkeland is the most prominent example, as it could be the world's first fully autonomous container ship built by Norwegian company Kongsberg. The vessel is supposed to have advanced digitalized

functions such as autonomy, electric operations and zero emissions (Kongsberg, 2022). This type of digitalization of large vessels sparks interesting aspects of the future such as more efficiency, a higher degree of implementation and a human-machine balance.

Opportunities and challenges with increased technology

One can already see how digitalization is changing job designs and descriptions in our everyday life. For example, the increased installation of self-checkouts at grocery stores is now an alternative many people choose. Job designs are being revolutionized and this obviously has an effect on the worker's job description. According to Gibbs and Bazylik (2022), the maritime segment will witness many routine and manual labor tasks being transformed into digitalized and automated processes. This will cause new routines, opportunities and challenges within the maritime industry (Gibbs & Bazylik, 2022).

The research suggests that the opportunities of the new technology are that it increases productivity and facilitates innovation. With greater use of machines and technology one gains data that can be analyzed, which gives companies the benefit of better prediction. Technology taking over tedious tasks can also allow workers to interact more in social settings such as teamwork and collaboration (Gibbs & Bazylik, 2022). The article also argues that prior automation has never led to mass unemployment, and therefore in the future, we could possibly see new types of jobs and work tasks rather than people getting unemployed.

The challenges the increased technology could bring, according to the same article is that digitalization eliminates the jobs that are done today. It could also put workers into a tricky situation since the technology would likely require training and preferably higher computer skills (Gibbs & Bazylik, 2022). This would be especially challenging for workers in the midst of or late in their careers, but perhaps not so much for new graduates, if provided with relevant education. The article also emphasizes the rapid speed at which machines are evolving and a concern for whether or not we are able to adapt to the technology fast enough. This raises an interesting concern on whether the maritime industry will be able to take care of both old knowledge and at the same time merge new competencies.

Some articles claim that the biggest negative outcome of the development of autonomous ships is that the operators are better at reacting and analyzing situations out of the ordinary while being present. McCarthy and Kidd (2019) state that because of the lack of human interference the more autonomy we bring into vessels at sea, the more accidents and failures it can cause. The article explores the negative evolution of autonomy in shipping and claims that it is impossible to compute a way out of every situation. The article state that because of these factors, operating semi-autonomous vessels is way more realistic and safer than fully autonomous vessels in the future (Mccarthy & Kidd, 2019).

However, other articles claim that humans as a guarantee for safer and smoother shipping are not realistic either. Stępien (2022) states that statistics and data show that maritime accidents are caused by human error in 60-95% of the cases (Stępien, 2022). The reasons for human error accidents could be fatigue, recklessness, overconfidence, poor communication and risky behavior. Supported by Broek, Griffoen and Drift, who state that autonomous shipping will be more resilient than traditional shipping because the accident rate will be reduced by 80% since humans are being replaced by technology (Broek, Griffioen, & Drift, 2020).

Li, Oh, Zhou and Yuen (2022) explore the increased safety and reduced number of accidents at sea with the usage of digital tools and autonomy from a more nuanced view. The article state that MASS needs to be just as safe and secure as traditionally manned ships, and ensuring this will likely enhance maritime safety. The article further explores how one cannot rule out human accidents although digitalization is increasing. Human-technology interaction, communication and connection between hardware and software can cause entirely new risks if not dealt with correctly. Therefore, the article emphasizes the need for risk analysis and risk understanding for technical improvements and accident avoidance (Li, Oh, Zhou , & Yuen, 2022). If these concerns are taken into consideration, it would seem as if a digitalized maritime industry could upheave safer operations.

The importance of the balance between humans and technology is repeating itself throughout the article searches. Having situation awareness is considered a key focus for autonomous shipping. Endsley (2017) mentions the concept "*out-of-the-loop problem*" as a possible outcome of digitalizing ships. It means that humans will not make the right decisions either because they are not present at the ship when a situation happens, or they are not able to interpret the data in the correct sense. Humans are therefore out of the loop of the situation and not able to respond correctly (Endsley, 2017).

Yoshida, Shimizu, Sugomori and Umeda (2020) go into the same problem but call it a lack of ship sense. Ship sense is the knowledge of bridge navigators for safe maneuvering. This involves making decisions for the ship's operation based on movement, environment and hearing information on the bridge. Therefore, going into the thought of an unmanned, autonomous ship one must consider whether the ship sense is ensured amongst the crew and operators. The article continues to describe that most MASS systems will have backup functions onboard and on land so that the safety issues are dealt with by the operator in case of MASS system failure (Yoshida, Shimizu, Sugomori, & Umeda, 2020). A remote control center is therefore considered very important when discussing safety on autonomous ships. The reason this is considered important is because reskilling and practice on situation awareness in remote ship operations would seem like a possible way to prepare future maritime workers.

Competence in school and workplaces

An important aspect to consider while discussing digitalization in the maritime industry is the competence one can see in education and workplaces today. As of now, there is a focus on digital skills in schools and workplaces. Having a technological common sense and understanding is essential for studying and entering work life. Today's maritime competence can be described as a standard called STCW (Standards of Training, Certification and Watchkeeping). The entire STCW will need to be readjusted in order to fit the operations of autonomous ships (Vakil, 2022). This needs to be done in order for international standards to be in line with safe operations in the future, which are highly taken over by digitalization. The article also explores who will control these autonomous ships, and what training and competencies will be necessary. It all depends on the four levels of autonomy that are being

used, but the article concludes that autonomous ships will need a different type of expertise than we see being practiced on traditional ships today.

According to Kobylinski (2016), in a greater digitalized maritime industry, the need for operators with the right type of certification will increase. Operators today need to obtain knowledge about navigational safety, tools, meteorology and emergency procedures. This is considered important traditional skills to operate a vessel. The operators also need to have routines in different types of situations and be able to recognize danger over computers. The STCW explains the standard one has for training maritime workers, and it is fully possible that these standards need to be updated and modernized in order to line up with digitalization in the future (Kjellsen, 2021).

Emad, Enshei and Gosh (2022*)* describe that the education system is in great change in the maritime sector. To handle future ships and ports there will be a requirement for modernly skilled captains and operators that preferably have knowledge about IT and analytical tools (Emad, Enshaei , & Ghosh, 2022). The article also states that many port authorities have been offered new training programs that help them be prepared for scenarios such as cyber-attacks. It would seem that not only focusing on implementing new graduates with modern digital tools in schools, but also providing already working employees with relevant courses, would be effective in order to meet technological demands in the future. This is done to keep up with the evolution, and it would therefore be fair to assume reskilling and competence evolvement is key in a continuously more digitalized maritime industry.

Reskilling maritime employees

Moving on from the finds on competence we see today in schools and workplaces, it is prominent that future maritime skills will be something different than what we see currently. Emad, Ensheai and Ghosh discuss how training strategy and evolvement alongside digitalization will be essential for future operations at sea. This requires especially digital skills and digital analysis (Emad, Enshaei , & Ghosh, 2022).

The paper explores which cognitive skills will be beneficial in order to process a lot of digital information at once, which could be the case when operating an autonomous vessel. This information was received from the shore control centers, and also here training was concluded as essential. Such practice could be done through simulators and computer-based training, where usage of VR, gamification and 3D simulation will help seafarers and operators on board and on land. Having STEM competencies is also considered a big plus, which means having competence in science, technology, engineering and math. This research shed light on having a greater focus on computer ability and skills, in order to operate ships in the future (Emad, Enshaei , & Ghosh, 2022). One could see a potential change in the operations of ships, now being a practical profession evolving to a more analytic and digital workplace.

Endsley (2017), explores how in the future we might have to deal with multiple digital systems that have no standard of performance. This scenario where various autonomous vessels and systems require different types of backgrounds and courses lead to cause a software management challenge. It creates a situation where human operators will behave differently and there will be no general solution on how to react to different situations (Endsley, 2017). This could cause a need for learning digitalized systems consistently in for example schools and courses, and according to some maritime standards such as an updated STCW.

As mentioned earlier, remote navigators and operators will have additional challenges with operating an autonomous ship because of a lack of ship sense and environmental circumstances such as wind and waves (Broek, Griffioen, & Drift, 2020). The STCW skills are very much important both in knowledge and in practice, but the article argues that autonomous maritime operations will require some additional competence. This could for example be situation-awareness through 2D interface, meaning the ability to translate maneuvering changes and instructions from the MASS. It should also include experience with maneuvering different types of vessels, knowledge about sensors, remote maneuvering and finally non-technical skill such as teamwork, communication and leadership to improve safety (Broek, Griffioen, & Drift, 2020).

When thinking that future maritime workers may not need any actual practice and learning at sea, this might not be the case. Yoshida, Shimizu, Sugomori and Umeda (2020) uncover aspects where seagoing experience is necessary to evaluate the operation of autonomous ships, as well as cognitive skills, fundamental ship knowledge and practice in decision-making. This is explained as important in order to collect essential information from the vessel's environment. Once again it could be done through experience and practice since ship sense is mentioned as key for operation. The article also suggests simulation and VR (virtual reality) training as helpful tools in order to practice different scenarios (Yoshida, Shimizu, Sugomori, & Umeda, 2020). It would seem very possible and necessary to keep some traditional learning practices, but also reskill maritime workers and students for a more digitalized approach in the future.

Literature review summary

Following is a short summary of the most prominent findings in the literature.

- Today there are good definitions of MASS (Maritime Autonomous Surface Ships), although some researchers believe it is not realistic to define autonomous systems completely because the technology will merge the industry and vessels at different levels.
- Autonomous ships compared to traditional ships must be met with a certain competence and expertise, and this leads to work tasks being transformed. For example, a machinist can also become a supervisory controller.
- STCW (Standards of Training, Certification and Watchkeeping) and other standards for maritime training will need updates as technology continues developing.
- These changes could require reskilling the maritime worker, such as prioritizing higher computer skills. Reskilling could be done through for example VR, simulation and gaming. It is expected that schools and educational institutions will play an important role here.
- Traditional skills are however still considered important such as fundamental ship knowledge and maintaining the ship sense. Taking care of old and new knowledge will be beneficial for the maritime industry.
- Regardless of remote control or humans being physically present in maritime operations, new risks will emerge with increased technology. Risk analysis and risk understanding will be important.

Methodological approach

The method used to explore this master thesis and answer the research question is a literature review combined with a quantitative method, in the form of a distributed questionnaire. The literature review was based on searches for relevant articles recently published and the questionnaire is based on responses from key persons in both maritime and digital industries. The reason for using both methods was to gain a greater insight into what has been studied earlier, collect current opinions and provide aspects that could be considered further. Looking at scientific articles on the subject and combining them with data collection from the current maritime industry was considered an appropriate way to get a realistic picture of the situation and give suggestions for the future. The final goal of the method was to gain a greater understanding of the readiness for digitalization in the maritime industry.

A quantitative method

The distribution of the quantitative questionnaire provided descriptive statistics for the thesis. This meant collecting brief data from the survey that could be a summary of measures in society (Hayes, 2023). Descriptive statistics is a branch of statistics that deals with the summary and interpretation of data. Its main objective is to describe the characteristics of a dataset in a meaningful and concise way. It involves the use of various measures such as central tendencies, measures of variability, and graphical representations (Hayes, 2023). This can help us understand what we are researching for, and in this case, help suggest the challenges we face with increased technology in the maritime industry. The descriptive statistics in this thesis is the collection of various opinions on maritime digitalization.

Figure 3 - Illustrating the course of the methodology.

Design and pilot testing

Building a high-quality questionnaire is a crucial step in ensuring that the data collected is accurate, reliable, and informative. To create a questionnaire that generates quality answers, several steps can be taken. The survey was built in Nettskjema.no which has standardized designs which were of great help in the creation process. The questionnaire had four background questions and 13 questions on the topic. The survey was designed to gather opinions about the current state of digitalization in the maritime industry, as well as information about the competence reskilling that could be required in the future.

Firstly, when designing a survey the questions in the questionnaire should be clear and unambiguous, avoiding confusion among the participant. The goal of the survey therefore needs to be stated clearly in the beginning, so that the participants know what is being researched. The questions should be focused on the topic of interest, and each question should only ask about one specific aspect or idea. This will help to reduce confusion and provide clear guidance to respondents, leading to better-quality answers (Børsting, 2022). The questions were also phrased so they were not leading, meaning they had many options and alternatives of answers. This was done in order to get the most realistic outcome possible.

Example 1 - Clearly stated questions asked in the survey.

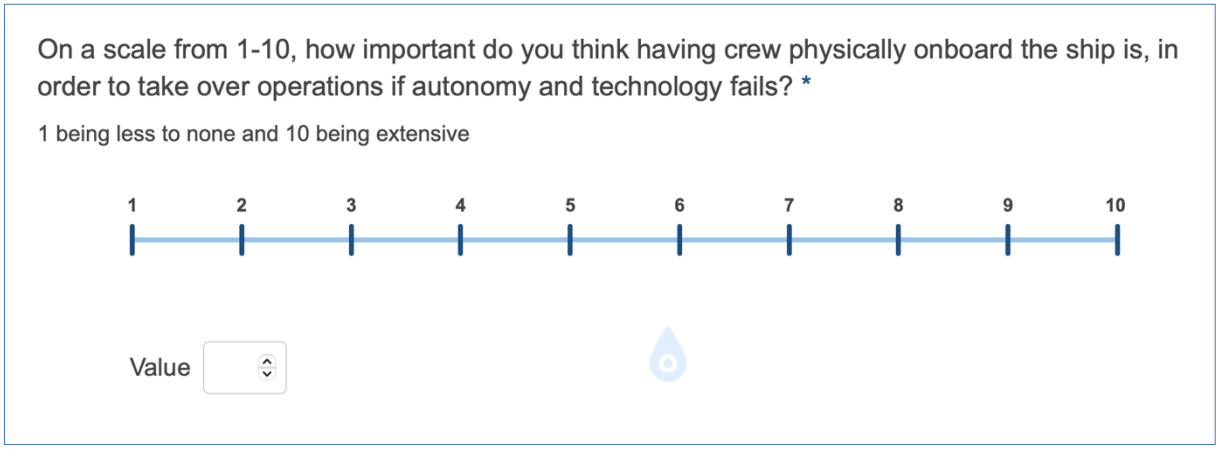


Figure 4 - Outtake from the questionnaire.

The questionnaire did not provide options that the participant might not agree with, by including alternatives such as "*not sure*". This was done so that the participants did not feel trapped by the alternatives in the questionnaire, which allowed for a more realistic outcome of the survey (Børsting, 2022). As one can see in Figure 5 below, the survey contains questions that give several options to avoid entrapment in the answers.

Example 2 - Question in the survey that does not entrap participants to the given answers.

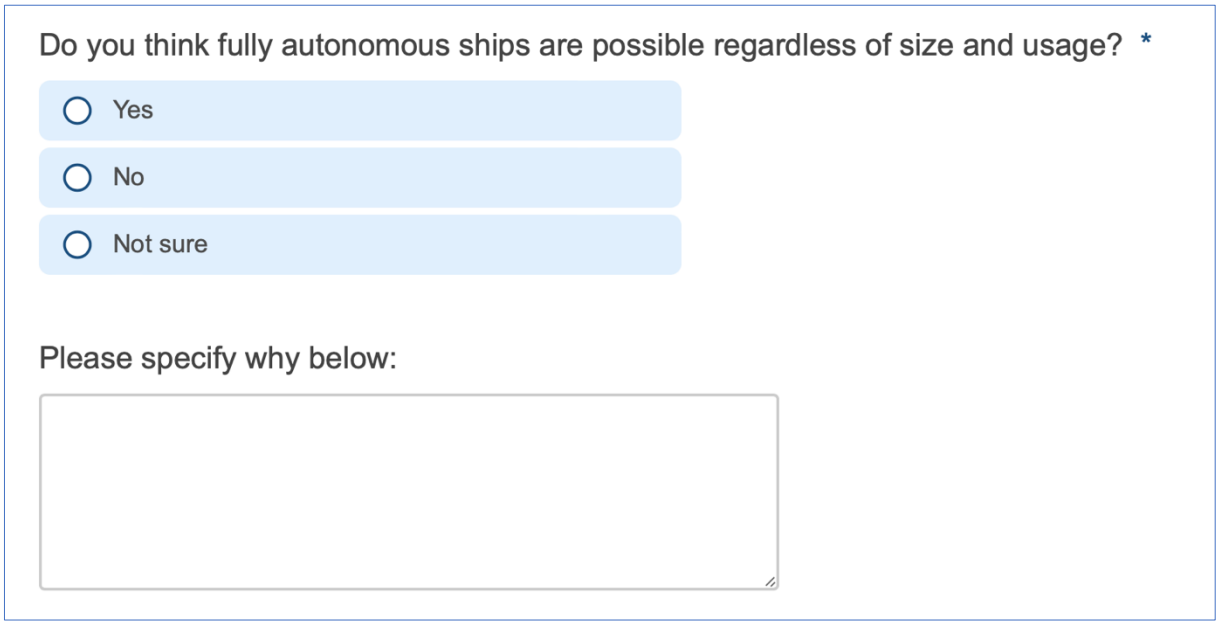


Figure 5 - Outtake from the questionnaire.

Secondly, the questionnaire should include both open-ended and closed-ended questions. Closed-ended questions offer respondents a choice of predetermined options of answers, while open-ended questions allow for more flexibility in responses. Combining both types of questions can help to ensure that a wide range of opinions and perspectives are captured (Ellingsen, 2021).

Example 3 – Combination of open-ended and closed-ended questions in the survey.

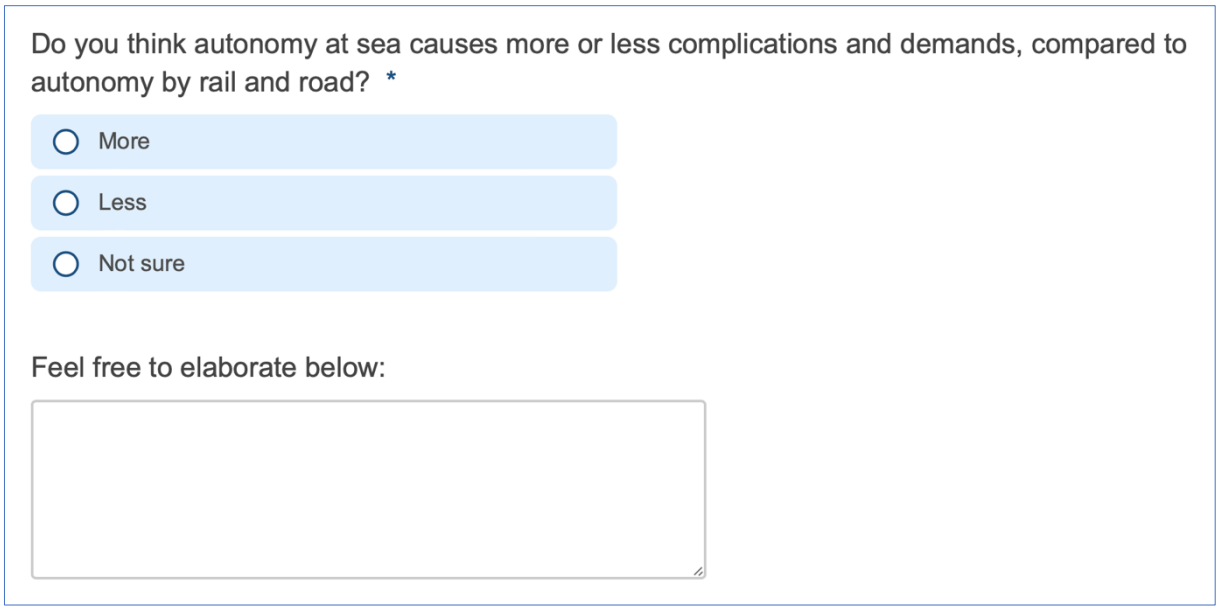


Figure 6 - Outtake from the questionnaire.

Thirdly, pilot testing the questionnaire before distribution can help identifying any potential issues or problems with the questions. From there one can refine the questionnaire to ensure a clear message and to generate quality answers (Harrison, 2007). This involved testing the questionnaire with the supervisor for a few rounds where feedback on the clarity, length, and relevance of the questions was considered. The test runs were done to ensure the quality of the questions and to provide choices of options in the answers.

Finally, the questionnaire should be designed in a way that respects the privacy and anonymity of the respondents. This means ensuring that the questions do not collect any unnecessary personal information and that the questionnaire does not require respondents to provide any identifying details. In this survey, the respondents were kept completely anonymous while participating and afterwards, with regard to their privacy and in order to gain the most truthful answers. The survey did therefore not ask for any sensitive information about the participants or keep any information such as IP addresses. There were only a few background questions at the beginning of the survey to ensure some maritime knowledge of the demographics.

Distribution

Distributing surveys online is an effective way to gather data and insights from a group of people in a short amount of time. By distributing a survey online, one can gather information from a wide range of stakeholders, including industry professionals, educators, and students. Once the questionnaire was designed, it was distributed through various channels, such as email, LinkedIn, and to university and industry associations. The questionnaire was also distributed physically by hand on Maritime Career Day 2023 on Campus Vestfold to maritime companies. The focus group for distribution was mostly employees in relevant maritime and/or technical companies found in Norwegian Shipowner Association (Norges Rederiforbund, 2023). The participants would preferably have some years of experience in the industry and on the subject so that they were able to reflect on the digital changes we see and estimate competence readiness.

There are several advantages and disadvantages to using surveys as a research method. The advantages are that questionnaires can be distributed to a large number of participants, allowing for a bigger sample size than other research methods. The data is standardized, because of the formulations of the questions, which allow for consistent data across participants and make it easier to analyze the data. Surveys can also be conducted anonymously, which can encourage participants to be more honest in their responses (Nardi, 2018).

The disadvantage of distributing a questionnaire online is that there could be a low response rate, particularly if the survey is lengthy or not intriguing, which can limit the generalizability of the findings. It could also produce a limited depth of data, since a survey can only collect data on what participants choose to share. Also, surveys do not allow for follow-up questions or the collection of contextual data, which can limit the understanding of the results (Nardi, 2018). The last thing one has to consider when distributing such surveys is question bias. The questions asked in a survey can be considered biased if they are leading or unclear. Therefore, one should carefully consider the advantages and disadvantages of surveys when deciding whether or not to use an online survey. In this thesis, it was considered a good choice because of the given time limits and the actuality a questionnaire provides.

Example 4 – Question in the survey that could be used as an example of question bias.

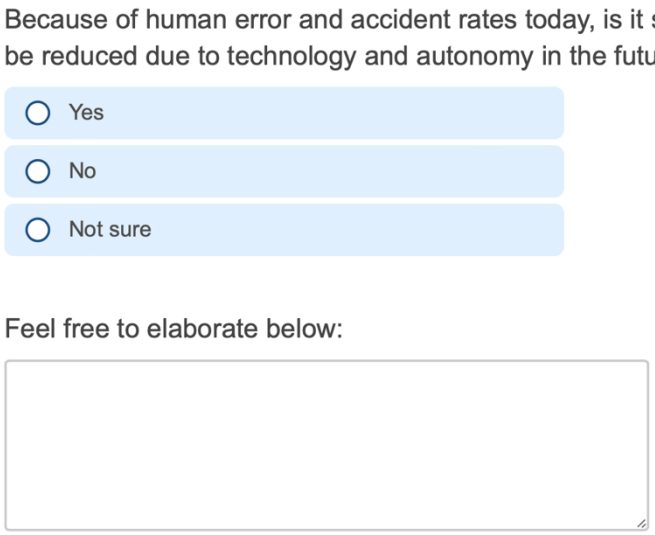


Figure 7 - Outtake from the questionnaire.

Because of the way the question is formulated in Figure 7, it could be considered somewhat leading. However, the question does provide several options of answers where the participant can fully state their own opinion clearly. The question was asked in order to explore whether the participants were optimistic about digitalization or not.

Data collection

The data collection was done through the results of the questionnaire. The questionnaire in Nettskjema has its own data collection function, which gathered all the questions and answers in a systematic PDF file. In that way, the data collection was an efficient process and it made analyzing easier. The findings from such a survey can be used to explain the development of education and training programs for maritime workers, as well as suggest the development and initiatives aimed at ensuring that the maritime industry is prepared for the digital future.

Reliability and validity

It has been an ongoing concern to maintain reliability and validity throughout the entire process of writing the thesis to ensure realistic and reflective research. Since the thesis is written based on both scientific articles and collected data from the questionnaire, it is important to always measure the quality of the work.

Reliability is whether or not the thesis provides reliable research and answers. One could say that the thesis is reliable if it provides the same outcome however and whenever it is conducted (Kirk & Miller, 1986). In order to capture the reliability of the questionnaire, Cronbach's alpha was attempted several times, which is a tool to measure consistency. Cronbach's alpha could not be calculated, due to the questionnaire containing 3 single-item questions that was measuring different things. Therefore the reliability through Cronbach's alpha of the questionnaire was attempted, but not successfully carried out. To gain such data reassurance would be of course a preference. One can also argue that a questionnaire sent out to certain participants does not ensure full reliability since the outcome is largely based on someone's opinion, but it could help give professional and realistic insight on the matter. It also gives a very current update on how the industry considers the situation which is important and reliable. The educational background of the participants also ensured that the answers were based on truthful knowledge. The reliability of this thesis is therefore taken into consideration.

Validity is considered when the author is measuring what is supposed to be measured (Frankfort, Nachmias , & DeWaard, 2015). The validity is ensured in this thesis through the variety of related articles involved, which shed light on different angles of the subject, both critical and positive points of view on maritime digitalization. Regarding the questionnaire, the meaning of the study was stated clearly in the beginning, creating no confusion on what the survey was about. The research questions were written and evaluated several times before being distributed, in order to provide a questionnaire of quality. The questionnaire was sent out to relevant businesses and key persons that could have extensive knowledge about the subject, both employees and students. The participants were given several options to answer each question so that they would give as authentic answers as possible. This was done in order to gain quality responses and to ensure the validity in the results.

Reflexivity

It was also important for the sake of the research to consider reflexivity. That would mean taking one's own beliefs and assumptions into consideration while writing and collecting data (Johnson & Dubeley, 2003). Therefore, some important questions I asked myself during writing the thesis were whether or not I had underlying beliefs on the matter and if my role and pre-knowledge passed any bias or judgment into the thesis.

Because of my educational background and knowledge of the maritime industry, it was important for me not to only verify the promising aspects of autonomy and digitalization as many articles and theories do. That is the reason why I chose to angle the thesis from a more skeptical point of view, investigating the possible struggles we might have with reskilling workers in an increasingly digitalized maritime industry.

It was important to look at not only the positive sides but more from a perspective where humans should not be replaced by digitalization and where technology could exceed us. One can often consider the industry they are a part of as failproof and ever-growing, but that is not always the case. It was also important for me to write a thesis that did not just verify my own beliefs and hopes for the maritime industry, and that is why I wanted to be enriched by other people's perspectives and opinions on the matter, through the questionnaire. Therefore it is fair to assume that reflexivity is taken into account while writing this thesis.

Other ethical aspects

Other ethical aspects taken into consideration are that the participant's identity and rights were always kept in the best interest, being that everyone was kept completely anonymous. When conducting research, it is important to take into consideration the General Data Protection Regulation (GDPR), which is a legal framework for the use of personal data of individuals in the European Union (NHO, 2023). GDPR provides specific guidelines and regulations on how personal data should be collected, processed, stored, and shared, and this was a very important focus in the methodology.

NSD (Norsk senter for forskningsdata) is meant to keep and protect personal information about the participants (NSD, 2023). Because of informed consent and no personal data collected, it was considered by me and my supervisor that an NSD application was not necessary. There would be no reason or way to collect the identity of the participants. Everyone involved in the thesis and the questionnaire was informed of the background and purpose of the research beforehand and the participants also had the right to withdraw from the survey at any time. The ethical aspects in this thesis therefore take good care of the participants involved.

Results from the questionnaire on maritime digitalization

Below is a concise summary of the results from the questionnaire. All figures are self-made in Excel. There were in total 32 participants in the questionnaire. Several questions had text boxes where the participants could elaborate as they wished. The most prominent elaborations are included in the analysis and discussion part of the thesis.

Background Question - What is your age?

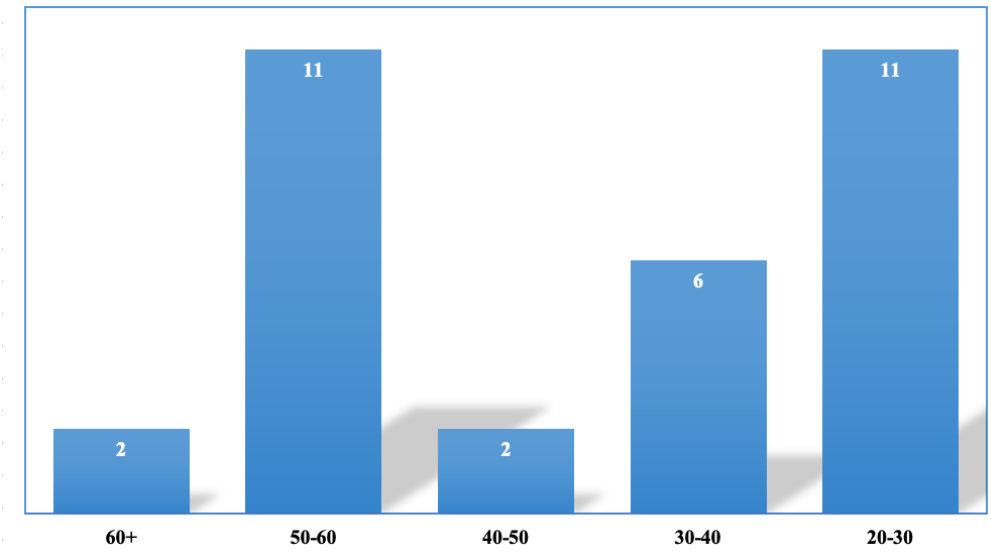


Figure 8 - Age demographics in the questionnaire.

Background Question – What is your knowledge of autonomy/digitalization/simulation?

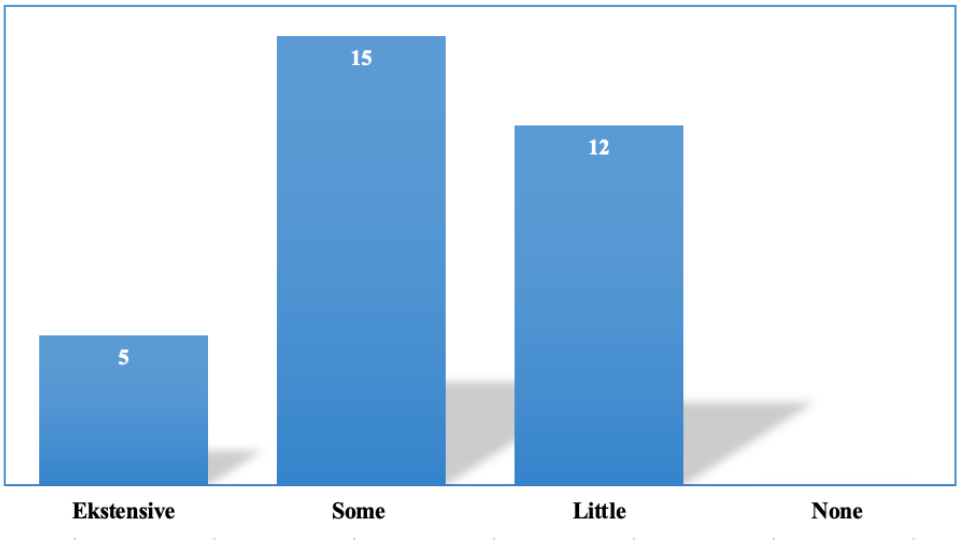


Figure 9 - Knowledge of autonomy/digitalization/simulation among the participants.

Background Question - Do you have experience working in a maritime company?

Summary: All of the participants had experience working in a maritime company. Some of the professions mentioned by the participants in this question were ship agent, chief officer, deckhand, electrician, navigator, purchaser, salesperson, engineer and in HR.

Background Question - Do you have experience working in a technology company?

Summary: Some, but not all of the participants had knowledge and experience from working in a technology company. Some of the professions that appeared here was a programmer and tech consultant.

Question 1/13 – On a scale of 1-10 how important do you think knowledge of autonomy will be in ship operations in the future?

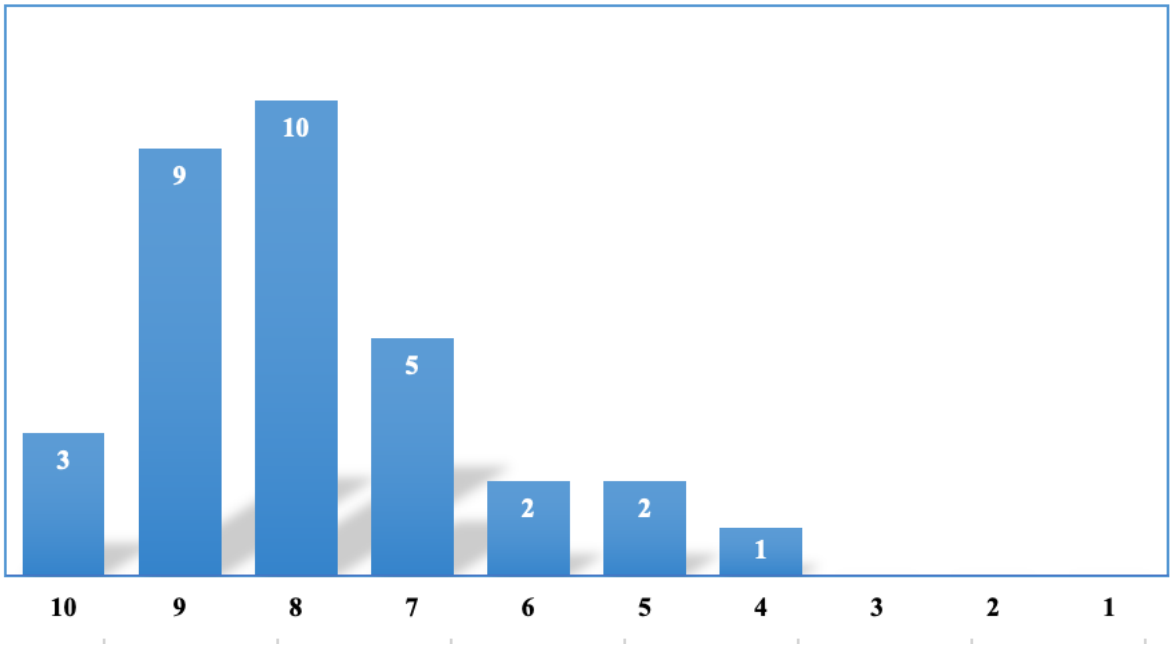


Figure 10 - How important the participants considered knowledge of autonomy in the future.

The average score is 7,88.

Question 2/13 - How likely do you think autonomy will take over most human interaction and work tasks onboard ships in the future?

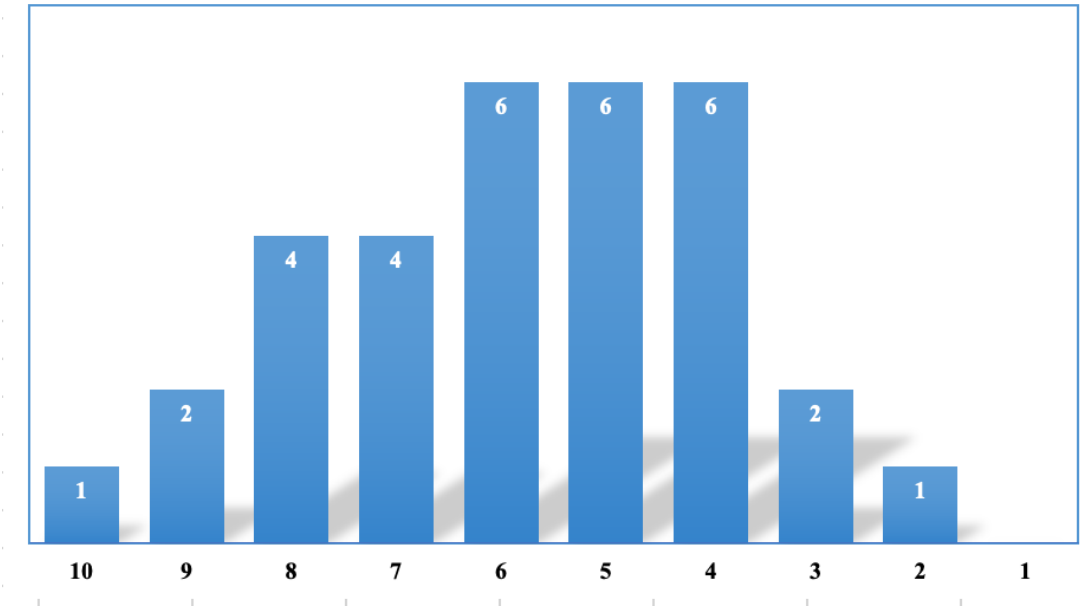


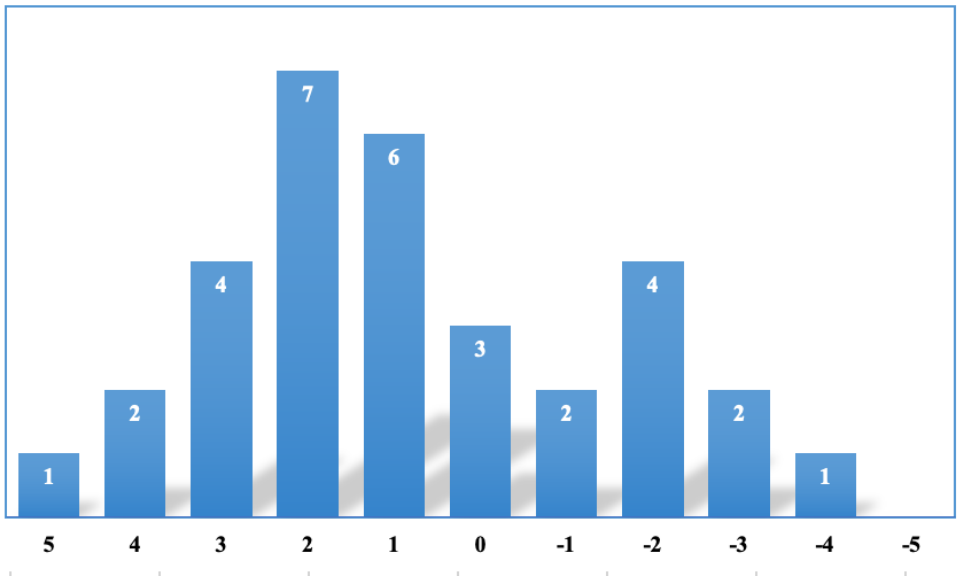
Figure 11 - How likely the participant thought autonomy would take over in the future.

The average score is 5,81.

Question 3/13 - How much do you think IT skills could have greater relevance than traditional navigation skills in the future for seafarers?

Important note: IT is closer to 5 and Navigation is closer to -5. The purpose of the scale was for the participants to evaluate the competencies against each other.

IT



Navigation

Figure 12 - The prioritized competence for seafarers in the future.

The average score is 0,78, meaning leaning slightly more toward IT.

Question 4/13 - On a scale from 1-10 how likely will competence requirements from universities and education change with regards to demands on operating autonomous vessels?

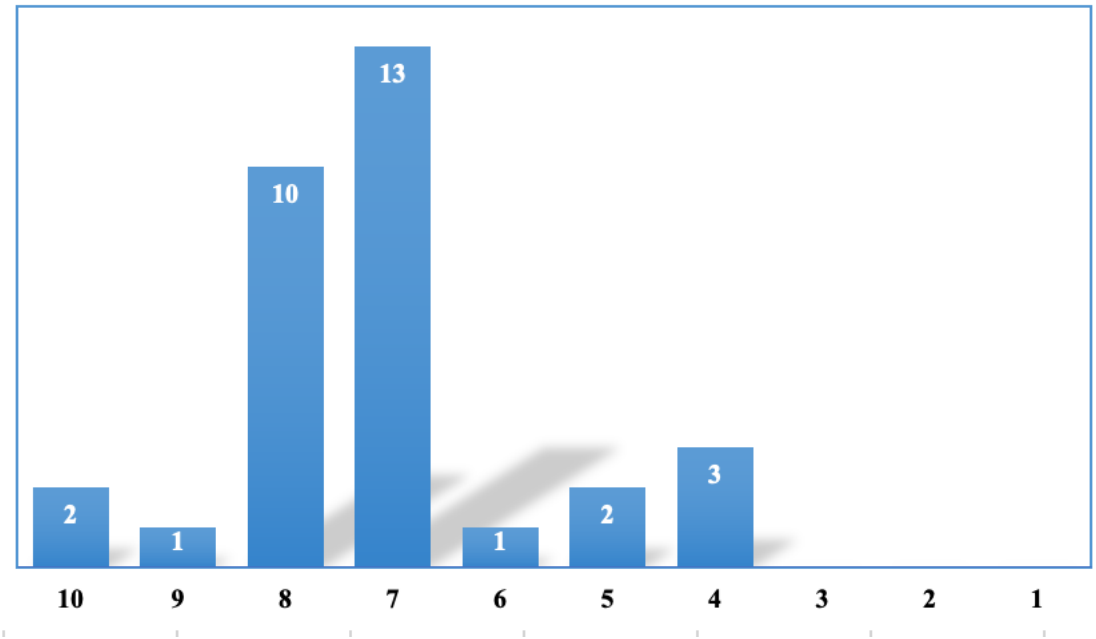


Figure 13 - The change of competence requirements for operation of autonomous vessels in the future.

The average score is 7,13.

Question 5/13 - Rank how important you consider these competencies for future maritime operations.

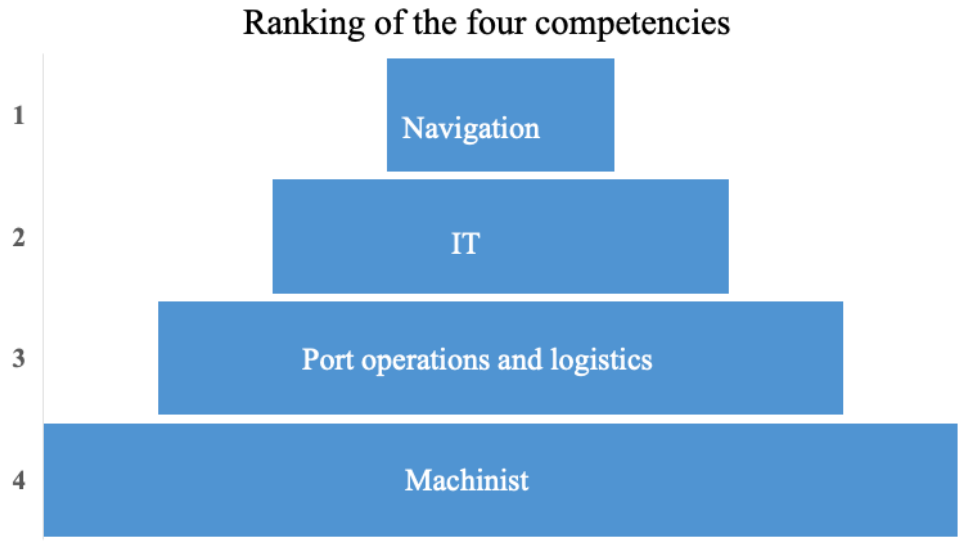


Figure 14 - The competencies ranked after importance from 1-4 (1=most important, 4=least important), with regards to future maritime operations.

Question 6/13 - Please choose which alternatives you think could be taken over by autonomy onboard ships.

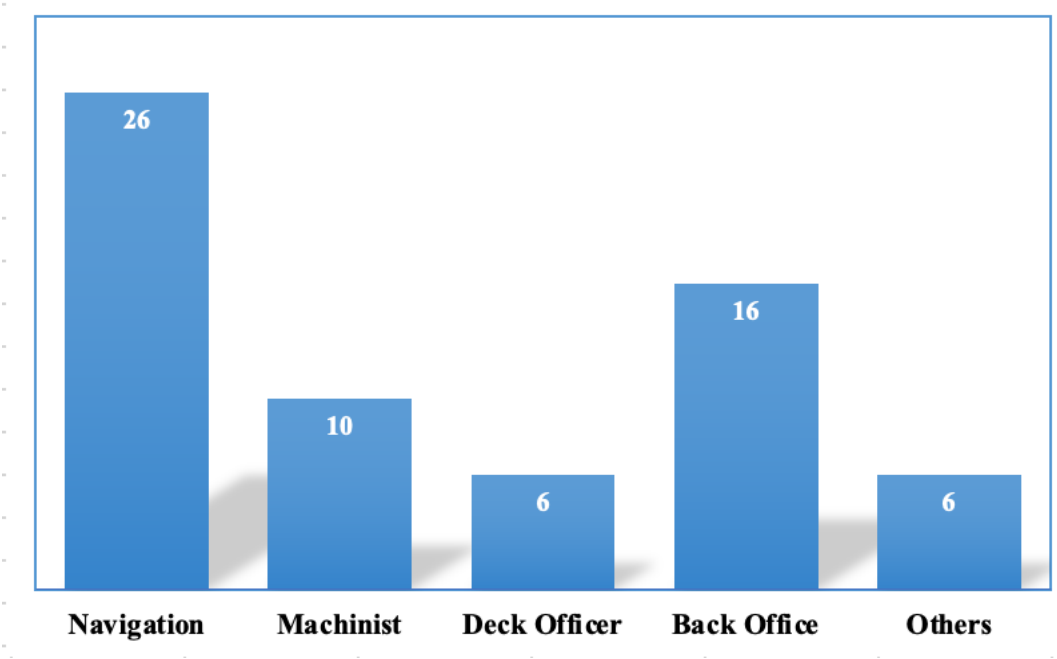


Figure 15 - Competencies that could be taken over by autonomy in the future.

Question 7/13 - On a scale from 1-10 do you think that autonomy onboard ships could to some extent be a standard in the future?

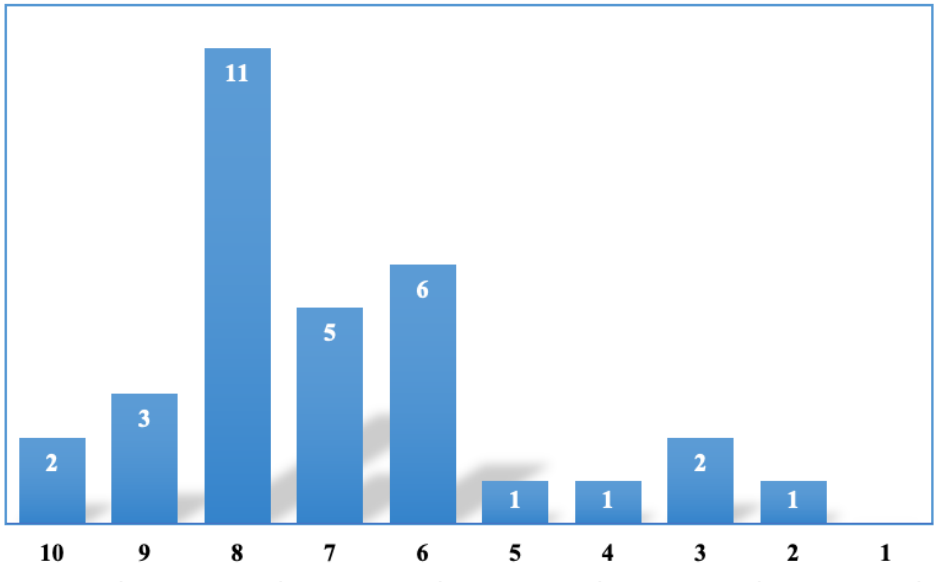


Figure 16 - The likeliness of autonomy being a standard in the future.

The average score is 6,97.

Question 8/13 - Do you think fully autonomous ships are possible regardless of size and usage?

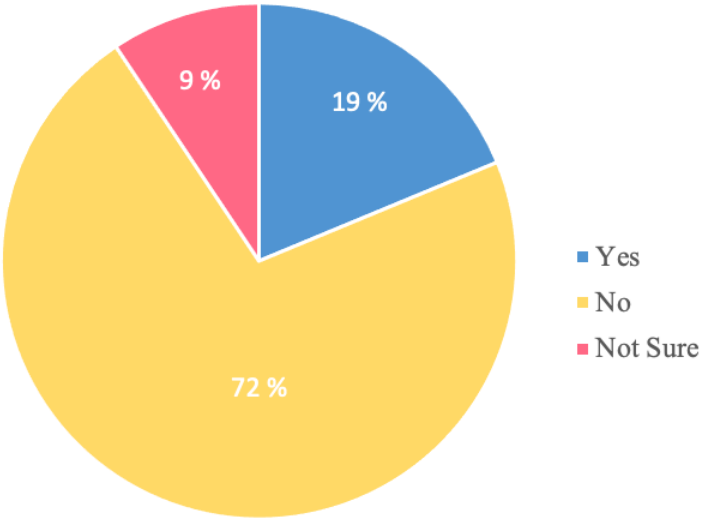


Figure 17 – The likeliness of fully autonomous ships in the future, based on participants' opinions.

Question 9/13 - On a scale from 1-10, how likely do you think experience with simulation and programming will be a requirement when hiring future sailors in maritime companies?

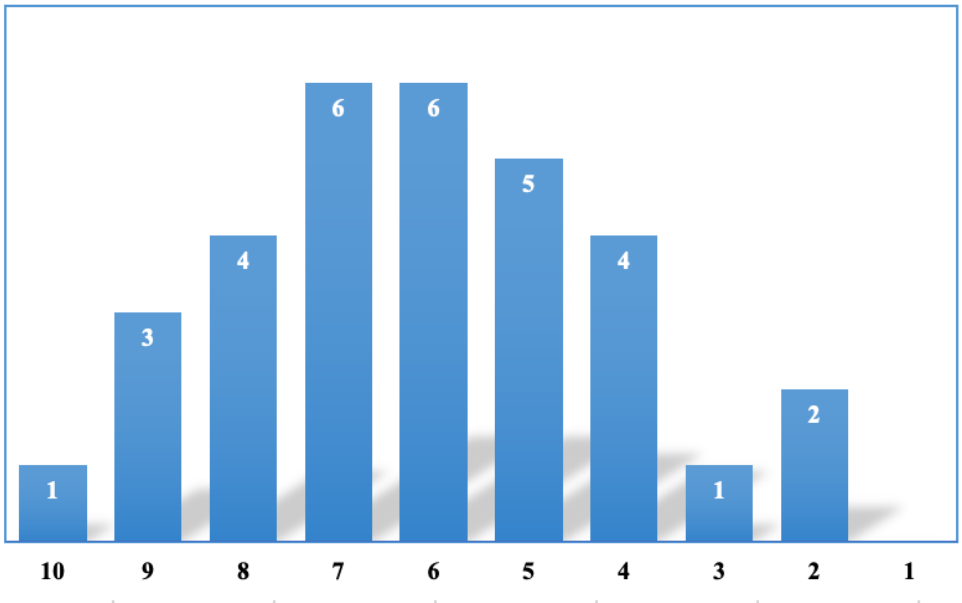


Figure 18 – The need for simulation and programming experience when hiring in the future.

The average score is 6,09.

Question 10/13 - Because of human error and accident rates today, is it safe to say that the chance of accidents will be reduced due to technology and autonomy in the future?

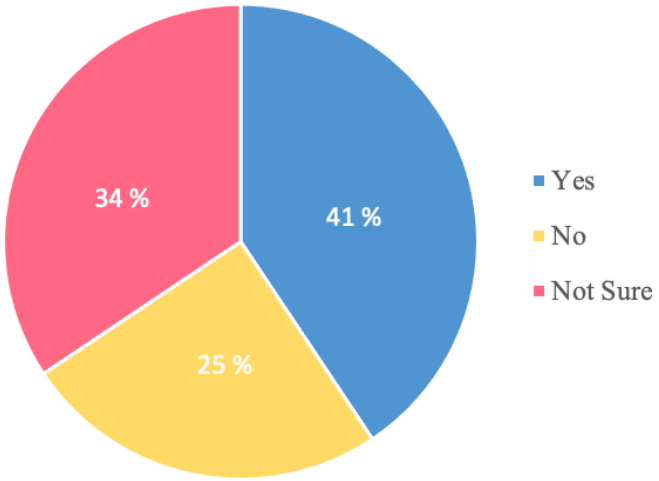


Figure 19 - The likeliness of accident rates being reduced due to increased technology.

Question 11/13 - Do you think autonomy at sea causes more or less complications and demands, compared to autonomy by rail and road?

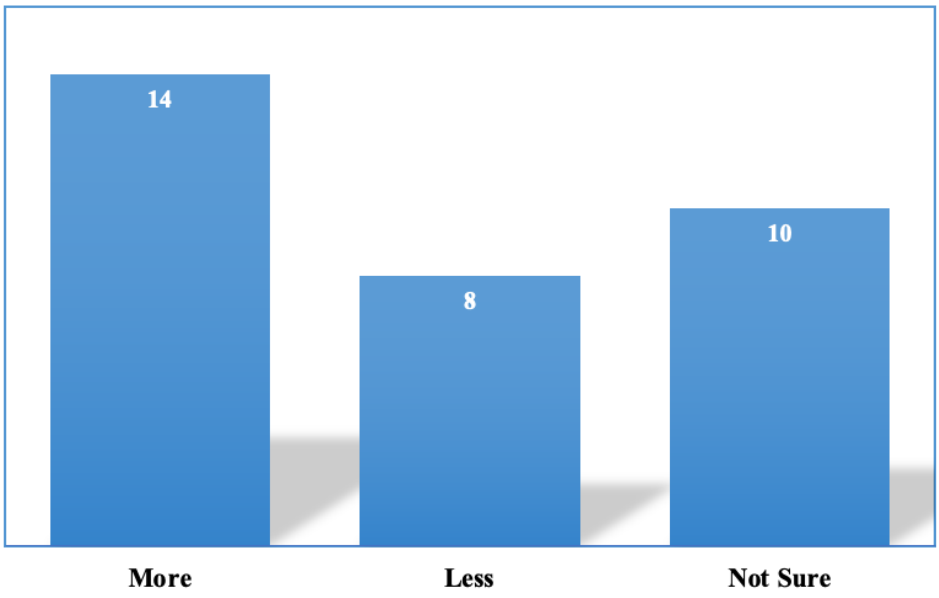


Figure 20 - Whether the participant thought there would be more or less complications with autonomy at sea.

Question 12/13 - On a scale from 1-10, how important do you think having crew physically onboard the ship is, in order to take over operations if autonomy and technology fail?

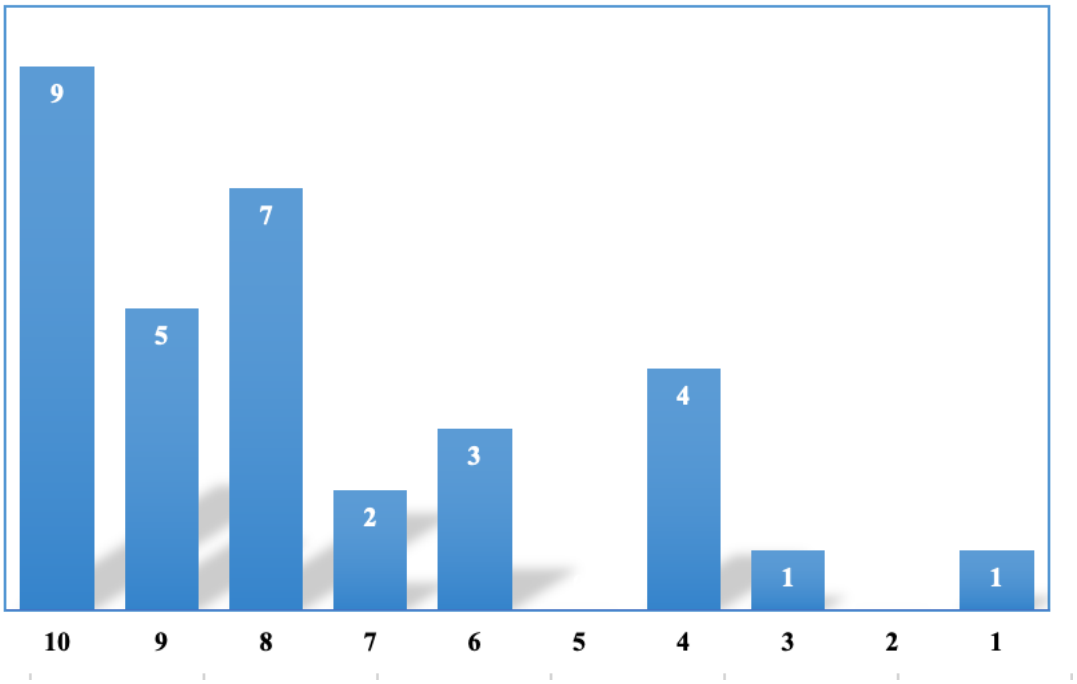


Figure 21 - The importance of crew physically present on ships.

The average score is 7,59.

Question 13/13 - Do you think the maritime industry is equipped and ready for the digital transformation we see happening today?

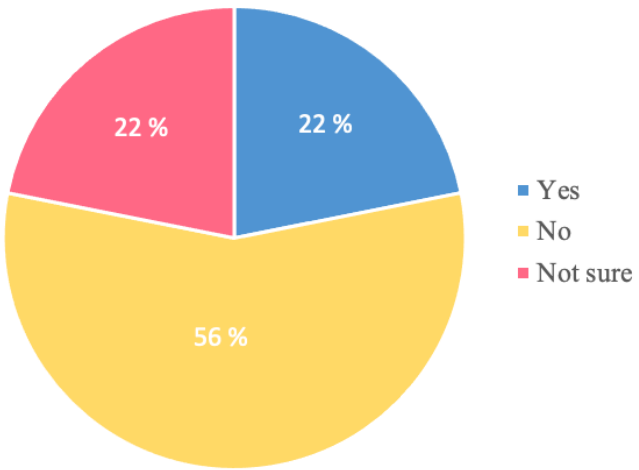


Figure 22 - Whether or not the maritime industry is ready and equipped for the digital transformation.

Analysis and discussion of the results

Once the questionnaire results were collected the analysis could be initiated. The findings could be used to inform and suggest the knowledge of the digital development of maritime education and work, as well as answer the question of whether the maritime industry is prepared for a digitalized future. Below an analysis and discussion of the most important findings in the questionnaire will be presented.

Introduction questions

The first part of the survey was questions on the participants' backgrounds. As mentioned this was done to ensure some knowledge among the participants, but not to gather anything that could identify them. There was a total of 32 participants in the survey, which was considered a sufficient amount for the research. All participants had maritime backgrounds and knowledge of the subject, and 10 participants had additional knowledge of digitalization and technology. Most of the participants were either between 20-30 or 50-60 years old, as one can see in Figure 8.

Levels of autonomy

In question 1, on a scale from 1-10, the participants considered the importance of knowledge of autonomy in ship operations in the future at an average of 8, which is high. However, in question 2, they thought that the likeliness of autonomy taking over most human interaction and work tasks onboard a ship in the future, at an average 5 out of 10. This states the importance of digital evolvement, but perhaps not a guaranteed autonomous takeover in the maritime industry. The reason why is that it could be more realistic to envision a period of transition and implementation of autonomous tools at first, before operations are fully autonomous.

In question 3, the participants considered navigational skills slightly more important than IT skills, although they came out very close to each other. However, they thought that it’s a 70% chance that competence requirements will change in education, which one can see in question 4. When asked in question 5, which of the following competencies they consider the most important for future maritime operations, navigation comes out at the top, with number two being IT, number three being port operations and logistics, and machinist as number four. This does not mean that they didn’t consider numbers two, three and four at the ranking as important,

but they were asked to scale the selected competencies in order to map out the possible key competencies in future maritime operations.

However, in question 6, they also considered navigation to be the competence most likely to be taken over by autonomy onboard ships in the future. This implies that the participants consider navigation as both the most important and also most likely to be influenced and affected by digitalization. It raises an interesting concern that a highly valued and important maritime capability may be subject to change in the future.

The participants also had the opportunity to click alternative *Others* in question 6 and elaborate in the text box below. Some of the responses of areas that could be taken over by autonomy were *"Automatic reporting, remote surveys and inspections, automation of decision processes"* and *"cargo handling".* Getting insight from the participants on other areas of maritime operations that are at stake of being replaced by technology was considered valuable information because it shed light on other competencies that are prone to efficiency and possible replacement.

In the same elaboration section, some of the points being made by the participants were: *"Fully autonomous ships are far from being realistic. One has to be aware of the differences between remote-controlled, partly autonomous and fully autonomous. The roles on board and on shore will change and new roles will develop, but the competence and professions will not be replaced. Seafarers will require a diverse and higher level of competence".* The statement verifies the theory on STCW needing updates that reflect the digital development in the industry, and that there will be a need for technologically skilled captains in the future (Emad, Enshaei , & Ghosh, 2022).

Another insight in the same question was *"I believe the risk of going full autonomous in the deep sea segment is too high. Normal navigation and less demanding tasks can be controlled by AI, but not having any local oversight can result in catastrophe. A ship is highly vulnerable against IT attacks and anyone who has worked onboard ships knows that even though you can reduce the risk from the human element, there must be an oversight since you never know what can happen".* It brings up not-so-unfamiliar concerns on whether a ship such as Yara Birkeland is as realistic as one might envision. In theory, we have read that autonomous ships will need a

different type of expertise than traditional ships and therefore reskilling maritime workers (Vakil, 2022). On this matter, the theory matches the elaborations of the participant.

The need for physical presence

One of the goals of the thesis was to uncover aspects of maritime labor and operation that perhaps should not be replaced by technology and autonomy. It is difficult to provide a definitive answer through findings in the questionnaire and literature. However, the questionnaire uncovers skepticism amongst the participants about humans not being physically present on ships. In question 5, machinist was the competence lowest on the ranking of importance for future maritime operations, but at the same time least likely to be taken over by autonomy in the future, as shown in figure 15. The statistics can be interpreted in many ways, but it is prominent that machinists are essential on ships, whether they are traditional or digitalized. Since semi-autonomous ships are the most likely digitalized vessel to operate in the nearest future, machinists should be considered important and necessary to have onboard and therefore an area of competence where pure autonomy might not be sufficient to take over.

Elaboration from a participant on the same question was *"Machinery may be partially taken over. It depends on what type of machinery we will have onboard. Batteries can be remotely controlled while combustion engines still will need people onboard. It is likely that we can have less competence onboard and support from shoreside*". The results from the questionnaire indicate that machinist is a profession that is more difficult to replace with technology, which makes sense due to their physical presence. As theory suggested their role in the future could be as more of a supervisory controller (Endsley, 2017). Other research emphasizes the need for bridge navigators as a necessity to maintain the ship sense (Yoshida, Shimizu, Sugomori, & Umeda, 2020). One could envision functions for a supervisory controller to be monitored from shoreside, but some work tasks might require a physical presence on board in order to maintain ship sense and safety.

In this case, autonomy is unable to fully replace humans in all maritime labor. It would therefore be fair to suggest that for example some machinists will be required onboard the vessels in order to perform safe operations, regardless of digitalization. In other words, these are areas of competence that humans supply that should not be fully replaced by technology.

Autonomy as a standard

Question 7 asked the participants if they thought on a scale from 1-10, that autonomy onboard ships could to some extent be a standard in the future. The average score ended up at 7 meaning that most of the participant thinks this is a realistic outcome in the maritime industry. However, in question 8, when asked if the participant thinks fully autonomous ships are possible regardless of size and usage 70% of them answered no. Most of the participants think that autonomy can to some extent be a standard in the future but at the same time, fully autonomous ships are not likely for maritime operations. It highlights that a stage of implementation and use of autonomous tools is more likely than operations based on solely autonomy, and that for example humans are the link between technology and operation.

When asked in the same question to specify why, some of the points being made by the participants were *"Some ships I believe can be fully autonomous, but in general, I believe it is more of a tool to help and assist the crew. Also, it can reduce the number of skilled crewmembers needed onboard".* Another point being made was *"I think it might be fully possible in some shipping segments like bulk or container but there are other segments that I think still require massive communication and coordination between humans like offshore (oil & gas) and offshore wind. Where more technical operations and liftings are required*". If one looks back at relevant theory it sheds light on some of the same aspects. Out-of-loop problem and lack of ship sense are phrases that explain problems that might occur if one removes humans entirely from the vessels (Endsley, 2017) (Yoshida, Shimizu, Sugomori, & Umeda, 2020).

Another point being made was *"The larger the ships are, the more difficult would it be to solve fully autonomous. Mainly due to sailing distance".* The participants make very valid points looking at different perspectives. In total, there is more skepticism about vessels being fully automated than optimism. Another participant wrote *"For the foreseeable future certain scenarios will only be partly autonomous. For example, cars are already autonomous and it works well in certain environments/conditions. But, driving a car in autonomous mode from Bergen to Oslo in a winter storm is another ball game. Still, a human can do it".* This leads to a situation where manned vessels with some autonomous functions are probably more realistic in the near future. However, one does not know what the standard for training and competence needs will be. The question of how the industry can set clear and realistic expectations for the

people working still stands. Most of it comes down to reskilling of maritime workers now and in the future, with perhaps a particular focus on navigators.

Question 9 asks the participants if they think it is likely that experience with simulation and technical skills such as programming will be a requirement for future maritime seafarers. The average answer was a 6 out of 10, and the answers were spread. The theory suggested computer-based training and experience with VR and simulation in order to modernize the maritime skillset (Emad, Enshaei , & Ghosh, 2022). Although it might not be a requirement, benefitting from the implementation of digital tools in education such as simulation could be a way of providing future maritime operators with additional knowledge and reskilling.

Human-technology balance

In question 10, when participants were asked if they thought accident rates were going to be reduced due to autonomy and technology the answers were again spread. Due to the formulation of the question it was expected that the participants leaned more toward answering yes, but the results were surprisingly variated. 40% of the participants said yes, 25% said no and 35% said not sure.

Some of the elaborations in this question by the participants may explain some of the spread: *"Only to some extent. Systems, software, and technology are also known for failing at times,. sometimes at critical times. Maybe time and money can be saved with tech & autonomy but I am not so sure of accident rates would go down. Every age of new implementations/testing is usually followed by a time of a lot of accidents".* Another statement was *"I think it depends a lot on the situation. The human factor will be removed, reducing risk on one side, but there is no guarantee technology will be completely failsafe".* The statements are important insights because as theory shows, the removal of humans at work is not ideal but having people physically present is also not a guarantee for safer maritime operations (Stępien, 2022).

On one hand, we have human error which could occur in every possible situation and industry, such as fatigue, stress and recklessness. On the other side, we have an increase in technology that eliminates a lot of the human labor we see today but at the same time needs human support. The golden mean would probably be semi-autonomous vessels, which could be safer and more realistic in the near future (Mccarthy & Kidd, 2019). It would seem that the skepticism in the

elaboration by the participants confirms that humans are not so replaceable, therefore a human-technology balance is perhaps essential. However semi-autonomous vessels will still provide new types of risks, and this can be avoided by reskilling maritime workers through risk analysis and understanding (Li, Oh, Zhou , & Yuen, 2022). To summarize the human-technology balance, a statement from a participant was *"You remove the "human error" factor, but the autonomy can also fail or misinterpret situations that humans could have avoided".*

Possible complications with technology

In question 11, the participants were asked if they thought autonomy at sea could cause more or less complications and demands, compared to autonomy by rail and road. This was asked in order to map out the skepticism for autonomy at sea compared to the autonomy we can see fully in operation today. Since autonomous vessels at sea are such a new concept, it seems that there are more negative than positive outlooks on the matter. The standards and definitions of MASS are not updated completely, especially with technology evolving as fast as it does. For example, the technology we use now might not be accurate in 5 years. As of today, there are mostly predictions of how autonomous vessels could function. Therefore, MASS practice would require reskilling and competence readiness, but also continuous adapting. The reason why is that it would be necessary to provide aligned competencies to the practices operated at the vessel.

The answers to question 11 were very variated and almost evenly spread between *more, less* and *not sure*. Some of the participants meant autonomy on ships would be more complicated than rail but less than road. Since ships don't follow tracks or roads it could be complications with for example berthing and obstacles. Some of the elaborations here by the participants were *"I think equal complications actually, every field has its own regulations, infrastructure, and risk assessments I think and therefore it can be an individual challenge of the same size",* and *"Making it less complicated: slow speed, few objects to interact with, larger equipment. Making it more complicated: Actual practices do not follow the book. Little standardization of equipment outside of the navigation systems. Lack of software handling skills in the maritime industry".* Related to this question, the participants saw the different types of technical, but also organizational issues with the increased technology at sea.

Question 12 asked on a scale from 1-10 how important the participants thought having crew physically onboard a ship in order to take over operations if technology fails. The average response was 7,5. It would seem as if the optimism for autonomy in public papers and in theory is high, but when people in the industry are asked about the potential complications with the technology there are several obstacles occurring such as competence, need for standardization and equipment failure. In conclusion, the human role in a digitalized maritime operation is considered important and perhaps unavoidable.

Digital readiness

In question 13, when asked if the participants thought the maritime industry is equipped and ready for the digital transformation we see happening today, over half of them answered no. A participant elaborated *"A lot of foundation work has to be implemented in order to achieve the real digital transformation. What we see happening today is companies realizing that they can benefit (financially and operationally) by employing digital solutions in their vessels and operations. This is creating a whole new market of supporting companies providing those services to supply these urgent demands from ship operators. But at this point, it is mostly isolated initiatives targeting a specific improvement".* It seems that we are in a digital shift where ambitions of autonomy are high, but the question of whether it is feasible still stands.

Some further elaborations on this question were *"The maritime industry at large is not ready, but there are a number of companies that have commenced their digital transformation journey".* Another insight was *"Bigger companies are equipped and ready, smaller companies will struggle".* The participants make a note of the changes in competencies in the future, and that especially navigators could be exposed to a lot of change. Being met with this insight, one would think that having STEM competencies (science, technology, engineering and math) will be very beneficial when aiming for digital readiness (Emad, Enshaei , & Ghosh, 2022).

In conclusion it looks as if the maritime industry today is not ready for the change we envision in the future. It would at least require new digital competence and reskilling (Emad, Enshaei , & Ghosh, 2022). To summarize the opinions on digital readiness, one of the participants' citations *was "Not today, but the Norwegian shipping industry is adaptable."*

Conclusion

The aim of this study was to write a thesis exploring the possible changes in the future of the maritime industry when it comes to digitalization, autonomy and reskilling of competence. The thesis provided exploratory insight through a literature review and the results from a distributed questionnaire. The questionnaire was developed and distributed online to relevant and familiar key persons in the maritime industry. Every participant had knowledge of the maritime industry and gave meaningful insight and valuable elaborations on the subject. The questionnaire uncovered variated opinions on the matter, some very optimistic about the digital change, and some not so optimistic about the readiness of the maritime industry. In total, there was skepticism toward increased technology, which emphasized the need for reskilling maritime workers.

The outlooks on digitalization and technological changes in the maritime industry are mostly positive but not every aspect is as optimistic as one would think. The literature on the subject uncovers promising development for the maritime industry, with some skeptical views on vessels going fully autonomous. However, the questionnaire uncovers not-so-optimistic views on this rapid evolution. It seems that the industry is met with the hasty change of technology and could struggle to adapt with the right competencies and reskilling of employees. The maritime industry is established and can in many ways be less susceptible to change. Some of the changes will not only have financial demands, but also organizational such as in schools and in workplaces.

The thesis has gained an understanding of the importance of humans in the maritime workplace, which leads to insight into what purpose technology and especially autonomy should have for us. Where to station people in future maritime workplaces is constantly being discussed. Due to increased technology, human error is addressed as a rarer outcome because of physical absence. Theory shed light on technology reducing human failure, although some research thinks that technology is not a guarantee for fewer complications and accidents. The questionnaire reveals that humans are not as replaceable as one might think and that a semi-autonomous maritime operation with humans involved is desired.

Finally, the research question will be answered:

How can the maritime industry ensure a workforce with the necessary reskilled competencies to succeed in a digitalized future?

To summarize there will be more autonomy, but fully autonomous ships have several challenges and might not be so realistic. Navigational skills are considered important and under the most influence of digitalization. This makes it a vulnerable profession, if not reskilled and adapted to technology in schools and education. Machinists and such competencies will still be required for hard labor or as controllers. The focus on providing maritime workers in the future with a modernized and adapted skillset, that is according to MASS and STEM will be beneficial for the industry. This can be done by assessing traditional maritime competencies such as machinists, while implementing navigators with digitalized tools and reskilled competence. In that way, one adapts the influenced competencies in correlation with technology and it could lead to the industry better facing the digitalization.

Limitations

The thesis could have benefited from improvements such as an even more specific questionnaire, digging further into the selected competencies. The thesis ended up being somewhat broad and kind of scratching the surface of several topics. It provided an overview of digitalization in the maritime industry, but these topics could be investigated even further on their own. For example, specifying which work tasks for a navigator would be changed due to digitalization. This was discovered when the questionnaire was collected and therefore became a learning point, but also a limitation to the analysis and results. The time frame does however influence such research.

Suggestions for further studies

A suggestion for further studies on the matter is that one could look into which areas should not replace humans with technology from an economic perspective. Looking at which processes will be too expensive or less efficient with autonomous processes could be an interesting approach to the subject and perhaps prepare the industry for the changes to come.

Another suggestion is to look at ways to improve two subjects, such as autonomous and navigational skills. Looking at how to integrate such subjects is a way to modernize and adapt to new technology. This research could be done by practice and can be very beneficial for schools and maritime workplaces.

The last suggestion for further studies related to digital readiness is the focus on cyber security alongside digitalization. Cyber security is most likely to gain importance over the years. Investigating how safe it is to operate vessels and shipments from shore while also being protective of cyber-attacks is a whole new way of maritime security and perhaps a necessary standard in the future.

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Figure List

Appendix

Digital transformation in the maritime industry

Oppdatert: 3. april 2023, 13:17

Questionnaire on digital development in the maritime industry

Development in technology is happening at a rapid speed and could potentially affect traditional maritime operations we see today in schools, education and workplaces. This questionnaire is developed to explore digitalized readiness in the maritime industry. Please feel free to give your own opinions on the questions. There is no right or wrong answer. Thank you very much for your time and participation!

Background information of participant

What is your age?

Antall svar: **32**

Svar	Antall	% av svar	
60+ years	2	6.3%	6.3%
50-60 years	11	34.4%	34.4%
40-50 years	2	6.3%	6.3%
30-40 years	6	18.8%	18.8%
20-30 years	11	34.4%	34.4%

What is your knowledge of autonomy/digitalization/simulation?

Antall svar: **32**

Svar	Antall	% av svar	
Ekstensive	5	15.6%	15.6%
Some	15	46.9%	46.9%
Little	12	37.5%	37.5%
None	0	0%	0%

Do you have experience working in a maritime company?

- 2. engineer 1980 - 1985
- Yes, offshore vessels within anchor handling and a wide range of subsea projects.
- I am a sailing chief officer and have been at Sea since 2010.

- I work as an Electrician onboard a SubSea vessel.
- Tidligere noe fartstid som sjømann. Jeg er vokst opp hos min bestefar som da var fisker og frakter på sjøen. Jeg høstet erfaring der som sommerhjelp og fikk dermed nok erfaring til å reise i utenriks sjøfart. På den tiden var det nok med den erfaringen til å mønster på en båt i utenriks fart.
- Several years sailing as a chief officer/2nd officer/DPO & able deckhand. Currently working ashore
- Yes. Have more than 30 Years experience from ship owning and ship operation, predominantly in commercial and managerial roles.
- Work with vessel automation at DNV
- Yes, Container segment and offshore wind segment.
- yes, have been working in maritime company for more than 20 years
- Yes, as A ships agent.
- I have worked on board ships and onshore with marine assurance and vetting for a combined time of 15 years
- Onboard and onshore experience from operations and assurance of maritime assets, including data driven solutions, simulations and the use of autonomous functions.
- Yes, +20 years with a maritime domain awareness technology company, training and managing R&D projects
- work today within the port business
- Yes, both from a ship design company and a maritime project development company
- Yes, short sea import and export
- With HR
- Developing rules and guidance for autonomy at DNV
- Yes, 27 years in DNV with newbuilding, certification, approval and fleet in service activity.
- I have worked in companies delivering equipment to the maritime industry, and hence know this industry to some extent.
- Working in various roles through the years, all within sales, with different responsibilites.
- Master mariner license in 1992, extensive experience from shipbourne operations, vessel management both in shipping and offshore operations. Additional 10 years in the norwegian coastal administartion mainly managerial position.
- Ship Agent
- Newly completed my masters within shipping and worked about a year or some plus internship
- Yes, since 2009
- Kind of - salmon export company
- Purchaser in LNG business for carriers
- I have seven months experience in a maritime company. I also have a Masters degree in Shipping.

Do you have experience working in a technology company?

Do you have experience working in a technology company?

- No
- No.
- Nope.
- No.
- I mitt nåværende arbeid er det behov til god kjennskap til teknologi.
- No.
- DNV
- Yes, In a company that designs, engineers, sales, and produces wind turbines both for onshore & offshore. This companies are also know as OEM's (Original Equipment Manufacturers).
- no
- No
- I have not worked in a tech company
- Onboard and onshore experience from operations and assurance of maritime assets, including data driven solutions, simulations and the use of autonomous functions.
- Yes. See above
- No
- Yes, please see above
- No
- Yes, 2 years as tech consultant
- Programmer and project manager in several industries
- Yes, I would claim that DNV is a teachnology company.
- Yes, I have spent most of my career working in various technology companies, ranging from oil & gas to maritime and aquaculture. I have worked for 36 years, in total.
- No.
- All businesses are somewaht tecknological:-)
- None
- no
- No
- I dont.

On a scale of 1-10 how important do you think knowledge of autonomy will be in ship operations in the

On a scale of 1-10 how important do you think knowledge of autonomy will be in ship operations in the future?

Antall svar: **32** Snitt: **7.88** Median: **8**

Svar	Antall	% av svar	
10	3	9.4%	9.4%
9	9	28.1%	28.1%
8	10	31.3%	31.3%
7	5	15.6%	15.6%
6	2	6.3%	6.3%
5	2	6.3%	6.3%
4	1	3.1%	3.1%
3	0	0%	0%
2	0	0%	0%
1	0	0%	0%

How likely do you think autonomy will take over most human interaction and work tasks onboard ships in the future?

Antall svar: **32** Snitt: **5.81** Median: **5.5**

Svar	Antall	% av svar	
10	1	3.1%	3.1%
9	2	6.3%	6.3%
8	4	12.5%	12.5%
7	4	12.5%	12.5%
6	6	18.8%	18.8%
5	6	18.8%	18.8%
4	6	18.8%	18.8%
3	2	6.3%	6.3%
2	1	3.1%	3.1%
1	0	0%	0%

How much do you think IT skills could have greater relevance than traditional navigation skills in the

future for seafarers?

Antall svar: **32** Snitt: **0.78** Median: **1**

Svar	Antall	% av svar	
5	1	3.1%	3.1%
4	2	6.3%	6.3%
3	4	12.5%	12.5%
2	7	21.9%	21.9%
1	6	18.8%	18.8%
0	3	9.4%	9.4%
-1	2	6.3%	6.3%
-2	4	12.5%	12.5%
-3	2	6.3%	6.3%
-4	1	3.1%	3.1%
-5	0	0%	0%

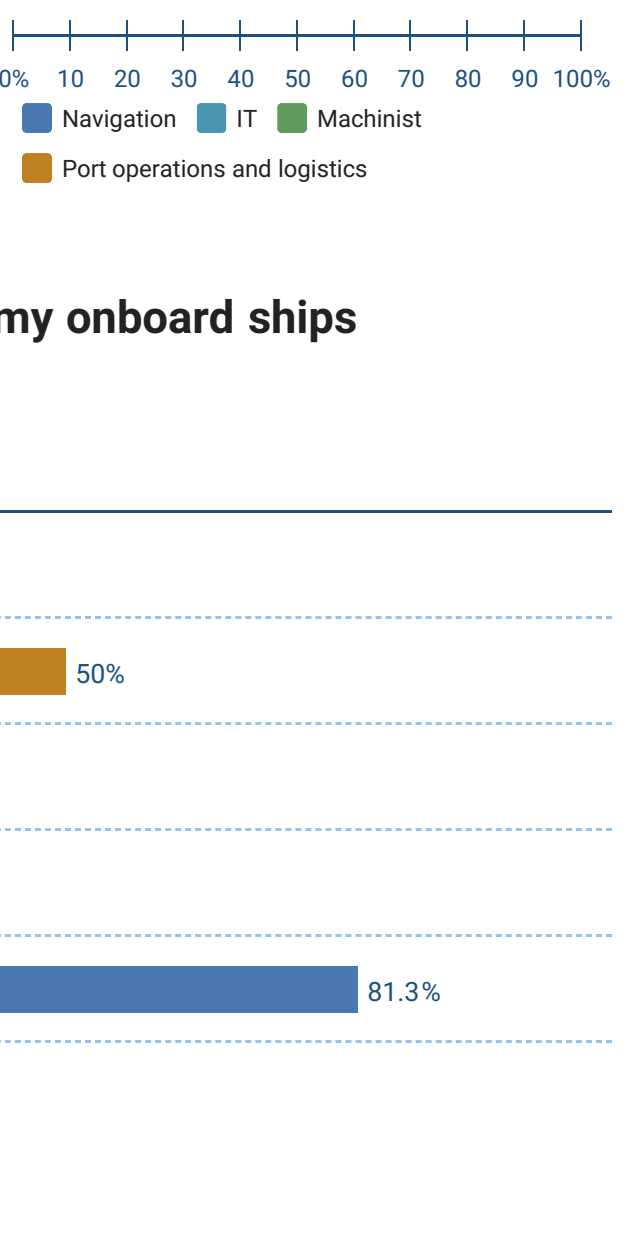
On a scale from 1-10 how likely will competence requirements from universities and education change with regards to demands on operating autonomous vessels?

Antall svar: **32** Snitt: **7.13** Median: **7**

Svar	Antall	% av svar	
10	2	6.3%	6.3%
9	1	3.1%	3.1%
8	10	31.3%	31.3%
7	13	40.6%	40.6%
6	1	3.1%	3.1%
5	2	6.3%	6.3%
4	3	9.4%	9.4%
3	0	0%	0%
2	0	0%	0%
1	0	0%	0%

Rank how important you consider these competences for future maritime operations

Svar	Navigation	IT	Machinist	Port operations and logistics	Diagram
Rank 1(most important)	20	4	2	6	
Rank 2	7	12	9	4	
Rank 3	1	13	7	11	
Rank 4 (least important)	4	3	14	11	



Please choose which alternatives you think could be taken over by autonomy onboard ships

Antall svar: **32**

Svar	Antall	% av svar	
Others (please specify in text box below)	6	18.8%	18.8%
Back office	16	50%	50%
Deck officer	6	18.8%	18.8%
Machinist	10	31.3%	31.3%
Navigation	26	81.3%	81.3%

Please elaborate:

- Fully autonomuos ships are far from being realistic. One has to be aware of the differences between remote controlled, partly autonomuos and fully autonomuos, The roles on board and and on shore will change and new roles will develop, but the competence and professions wil not be replaced. Seafarers will require diverse and higher level of competence.
- I believe the risk of going full autonomous in the deep sea segment is to high. Normal navigation and less demanding tasks can be controlled by AI, but to not have any local oversight can result in catastrophy. A ship is highly vulnerable against IT attacks and anyone who has worked onboard shups knows that even though you can reduce the risk from the human element, there must be oversight since you never know what can happen
- Level of autonomy will largely depend on shipping segment and trading area
- Automatic reporting, remote surveys and inspections, automation of decision processes
- cargo operations
- Electrification for shorter distances will change the need for competence on machinery
- Machinery may be partly taken over. It depends on what type of machinery we will have onboard. Batteries can be remotely controlled while combustion engines still will need people onboard. It is likely that we can have less competence onboard and support from shoreside.
- Cargo handling & logistics at harbours.
- Navigation of own vessel would be easy with todays technology. However interactions with many more vessels under human command may make this difficult. Reductions in crew numbers are propotional with the level of autonomy. Less people onboard the fewer are needed from a safety aspect.

On a scale from 1-10 do you think that autonomy onboard ships could to some extent be a standard in the future?

Antall svar: **32** Snitt: **6.97** Median: **7**

Svar	Antall	% av svar	
10	2	6.3%	6.3%
9	3	9.4%	9.4%
8	11	34.4%	34.4%
7	5	15.6%	15.6%
6	6	18.8%	18.8%
5	1	3.1%	3.1%
4	1	3.1%	3.1%
3	2	6.3%	6.3%
2	1	3.1%	3.1%
1	0	0%	0%

Do you think fully autonomous ships are possible regardless of size and usage?

Antall svar: **32**

Svar	Antall	% av svar	
Not sure	3	9.4%	9.4%
No	23	71.9%	71.9%
Yes	6	18.8%	18.8%

Please specify why below:

- See previous written answer.

- Yes i trust the shops will be autonomous to a great extent, but fully autonomous.. No! The biggest reason being the need of human interference for the sake of navigation. Now.. If all the ships of the world turn fully autonomous all at once.. Then it could work.. But as long as there is a single manned ship.. You need a human behind the wheels to Deal with that chap!
- Some ships i believe can be fully autonomous, but in general i believe it is more of a tool to help and assist the crew. Also it can reduce the number of skilled crewmembers needed onboard
- Autonomy should serve a purpose, i.e. it is no point in pushing for autonomy for the sake of autonomy. Segments/areas in which autonomous operation will result in a reduction of cost and risk overall, including having built in sufficient redundancy etc will be preferred. Hence my reply is that fully autonomous ships may be possible but not preferred for some sizes/usage areas.
- Depends on usage domain
- I think it might be fully possible in some shipping segments like bulk or container but there are other segments that I think still require massive communication and coordination between humans like offshore (oil & gas) and offshore wind. Where more technical operations and liftings are required.
- Large cruise ships with many passengers not likely..
- Only if every stakeholder (IMO, Flags, Port Authorities, Charterers, Ship Owners) is completely committed to allowing the fully automation of ships. Until this common ground is reached, fully autonomous ships at global commercial scale are far from reality.
- By answering "yes", it would imply that everything can be autonomous in all use cases. Everything is a "big word" and this would be a tall order. For the foreseeable future certain scenarios will only be partly autonomous. Example: cars are already autonomous and it works well in certain environments/conditions. But, driving a car in autonomous mode from e.g. Bergen to Oslo in a winter storm is another ball game. Still, a human can do it.
- The larger the ships are, the more difficult would it be to solve fully autonomonous. Mainly due to sailing distance.
- some operations are performed too seldom to be worthwhile automating. Some operations may be to specialized to lend itselves towards automation
- Possible for close to shore operation. Not likely for longer legs due to propulsion challenges. For some cargoes we need people onboard. A cruise vessel without a captain will most likely not be very popular because the cargo feel unsecured.
- Personnel transportation, and probably all transportation, at open sea will always have to be overlooked by qualified personnel.
- Complex operations will require human interaction.
- Its possible, but will not happen. At this time and the near future (10 years ahead) the cost of autonomy will be too high, governing bodies will also be 20 years behind the technoligy. But when the industry matures and costs are lower, then possibly fully autonomous ships are possible in all trades and sizes.
- Not all operations with ships can become autonomous
- I'm sure it's heading in that direction
- I think the economy will be a breaker as it will be easier and cheaper to use traditional methods
- With time there will be a shift towards autonomous ships, and especially without placing a time frame one the question. A thousand years from now fully autonomous ships are guaranteed.

On a scale from 1-10, how likely do you think experience with simulation and programming will be a requirement when hiring future sailors in maritime companies?

Antall svar: **32** Snitt: **6.09** Median: **6**

Svar	Antall	% av svar	
10	1	3.1%	3.1%
9	3	9.4%	9.4%
8	4	12.5%	12.5%
7	6	18.8%	18.8%
6	6	18.8%	18.8%
5	5	15.6%	15.6%
4	4	12.5%	12.5%
3	1	3.1%	3.1%
2	2	6.3%	6.3%
1	0	0%	0%

Because of human error and accident rates today, is it safe to say that the chance of accidents will be reduced due to technology and autonomy in the future?

Antall svar: **32**

Svar	Antall	% av svar	
Not sure	11	34.4%	34.4%
No	8	25%	25%
Yes	13	40.6%	40.6%

Feel free to elaborate below:

- Human error will be eliminated, but my knowledge says that the risk of a ship system failure is significantly higher when there is no one onboard to control and check. Sensors and equipment fail every day

- Only to some extent, systems, softwares, and technology are also known for failing at times… sometimes at critical times. Maybe Time and money can be saved with tech & autonomy but I am not so sure of accident rates with go down. Every age of new implementations/testing is usually followed by a time of a lot of accidents.
- Processes will no longer rely solely on human input/action. Automated systems will be able to identify outliers and misconducts in real time
- but it is hard to say when it will happen
- Yes, I would expect so as we will have system support prevention collision and other errors.
- I think it depends a lot on the situation. The human factor will be removed, reducing risk on one side, but there is no guarantee technology will be completely failsafe. A lot of testing and experience is required before fully implementing it. The risk of serious accidents with huge implications is very possible.
- Not really until all vessels are fully autonomous. One human error is enough, and this will be the case in the next 10 years.
- Yes you remove the "human error" factor, but the autonomy can also fail/misinterpret situations that humans could have avoided.
- Hard to tell, probably to say extent

Do you think autonomy at sea causes more or less complications and demands, compared to autonomy by rail and road?

Antall svar: **32**

Svar	Antall	% av svar	
Not sure	10	31.3%	31.3%
Less	8	25%	25%
More	14	43.8%	43.8%

Feel free to elaborate below:

- The trouble lies in vessel maintenance and the sheer length of time at sea.

- I think equal complications actually, every field has it own regulations, infrastructure, and risk assessments I think and therefore it can be an individual challenge of the same size.
- The complexity of the integration between manufacturers, the lack of standardization of requirements and the interaction between stakeholders is more complex and thus challenging in the shipping industry
- Making it less complicated: slow speed, few objects to interact with, larger equipment Making it more complicated: Ambiguity of COLREG. Actual practices does not follow the book. Little standardization of equipment outside of the navigation systems. small series of vessels/equipment. Lack of software handling skills in the maritime industry.
- International trade is complicated due to climate, culture and no fixed routes for the vessels.
- I am not sure whether it will impact complications much, but it will reduce the need for sailors - money saved for shipowners/operators in the long run.
- Ships do not follow tracks or tarmac roads.
- Rail sounds like the safest for autonomy.
- I would except big complications with berthing, obstacles etc. on road/rail the route is fixed to the road/railway
- There are more factors to take into consideration and the possible failure is more critical
- More than rail, less than road

On a scale from 1-10, how important do you think having crew physically onboard the ship is, in order to take over operations if autonomy and technology fails?

Antall svar: **32** Snitt: **7.59** Median: **6**

Svar	Antall	% av svar	
10	9	28.1%	28.1%
9	5	15.6%	15.6%
8	7	21.9%	21.9%
7	2	6.3%	6.3%
6	3	9.4%	9.4%
5	0	0%	0%
4	4	12.5%	12.5%
3	1	3.1%	3.1%
2	0	0%	0%
1	1	3.1%	3.1%

Do you think the maritime industry is equipped and ready for the digital transformation we see happening today?

Antall svar: **32**

Svar	Antall	% av svar	
Not sure	7	21.9%	21.9%
No	18	56.3%	56.3%
Yes	7	21.9%	21.9%

Please elaborate in text box below:

- Not at all.
- The maritime industry at large is not ready, but there are a number of companies that have commenced their digital transformation journey. Interesting to note that there is a close connection between decarb and digitalisation, inasmuch as digitalisation is an enabler for more optimized and efficient operation and thereby lower fuel consumption.
- The technology from ready, it will take a lot of time.
- A lot of foundation work has to be implemented in order to achieve the real digital transformation. What we see happening today is companies realizing that they can benefit (financially and operationally) by employing digital solutions in their vessels and operations. This is creating a whole new market of supporting companies providing those services to supply these urgent demand from ship operators. But at this point it is mostly isolated initiatives targeting a specific improvement.
- In general the maritime industry is very immature. Operating in Norway or any high-tech country it is easy to believe that ships are very advanced and the industry very mature. The majority of shipping is not there.
- Equipped, yes; ready, not so certain
- Bigger companies are, smaller companies will struggle.
- Noone is ever truly ready for change, but change always comes. Therefore, there is no alternative to not be ready.
- Not today, but the Norwegian shipping industry is adaptable.
- Changes in shipping take time, and there are many parties who will object to it along the way.