



# CHALMERS

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## **Digitalization in the future maritime engine control room** *It's Potential and Challenges*

Bachelor thesis in the Marine Engineering Program

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# **SAMMANFATTNING**

Sjöfartsindustrin är för närvarande den främsta globala transporttjänsten för handelsvaror idag och för att möta den ökade efterfrågan som förväntas komma, letar sjöfarten ständigt efter nya tekniska medel för att effektivisera sina fartyg. Många rapporter idag har gjort undersökningar om hur mer och nyare teknik på bryggan, påverkat nautikers arbetsmiljö där motsvarande arbete och föreskrifter mot maskinrummet saknas. För att hantera denna brist på forskning mot maskinrummet, har vi studerat närmare på hur maskinister idag hanterar nuvarande och kommande teknik, där en mindre undersökning genomfördes kring svenska och turkiska befäl inom det marina ingenjörsområdet. Frågeställningen som ställs i detta examensarbete, syftar till att undersöka maskinrumspersonalens synpunkter om digitaliseringen och hur de ser på den framtida utvecklingen i maskinrummet. Resultatet från intervjuerna visar att det finns flera utmaningar som kommer att bemötas för framtiden. En av utmaningarna är kunskap gapet idag inom el, elektronik och automation vilket har sin tur har lett till att maskinister har fått det allt svårare att utföra vissa typer av felsökningar, problemlösningar och med detta stoppat anpassningsbarheten för tekniken. Utöver detta behöver utbildning moderniseras, och regelverk standardiseras efter ny teknik för att bemöta framtida marknadens behov.

Nyckelord: Digitalisering, Maskinrum, sjöingenjör, kunskap, sjöfart, sjöfartsindustri.

## **ABSTRACT**

The shipping industry is currently the main global transportation service for commodities today, but the shipping industry is constantly looking for new technologies to streamline their vessels to meet the increased demand that is expected to come. Today, many reports have done research on how new and more technology on the bridge, have affected the working environment towards the personnel on the bridge, where the corresponding research for the engine room seems to be insufficient. To deal with the lack of research of the engine room, we have studied how the marine engineers handle the current and future technology, where a minor survey was conducted around Swedish and Turkish marine engineers. The question posed in this thesis, aimed to examining the engine personnels' point of view on digitalization and their perspective on the development of the future in the engine room. The results from the interviews revealed that there are several challenges within a near future. One of the challenges is the knowledge gap in electricity, electronics and automation, which has led to making it increasingly difficult to carry out certain types of troubleshooting and problem solving for the engineers and with this stopping the adaptation for some technical developments. In addition, education must be modernized, and regulations are standardized according to new technology to meet the market needs in the future.

Keywords: Digitalization, Engine control room, marine engineer, skill set, shipping, shipping industry.

## **PREFACE**

The purpose of this case study is to enlighten the problems and possibilities with more technology in maritime engine rooms and to exemplify what challenges the regulatory has towards new advanced technology, along with what kind of skill set is desired of our future marine engineers.

We, who have completed this thesis, would like to show our recognition and say thank you, towards everyone that have chosen to participate in our research for their dedication, time and for their welcome we have received. We would also like to thank our supervisor Monica Lundh and Chalmers University of Technology.

Mustafa Gundogdu  
Oscar Josefsson

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## Definitions and abbreviations

**AI:** Artificial Intelligence, is intelligence programming for computers to gain understanding.

**Autonomous vessel:** A vessel that has a higher degree of automation systems and can provide help in decision making on board or fully automated.

**AAWA:** Advanced Autonomous Waterborne Applications, is a project that is currently investigating and investing in the opportunity of autonomous vessels in the future.

**ECR:** Engine control room, a control room on board a ship

**ER:** Engine room, refers to a engine room on board a vessel.

**IR:** Industrial revolution

**IMO:** International maritime organization (IMO), is a standard-setting authority, responsible to develop and maintain a regulatory framework for international shipping. In other words, their role is to prevent stakeholders from cutting corners and compromising on safety, security and environmental performance.

**Kongsberg:** International organization, delivering high-technology solutions to industry (engine room, nuclear power plants etc.)

**MUNIN:** Maritime Unmanned Navigation through Intelligence in Networks, founded by EU to investigate unmanned shipping

**MASS:** Maritime Autonomous Surface Ships, is an alternative name for Autonomous vessels.

**MSC:** Maritime Safety Committee (MSC), deals with maritime safety and security.

**SARUM:** Safety and Regulations for European Unmanned Maritime Systems

**Rolls-Roys:** International manufacturer for both maritime and land-based vehicles

**SOLAS:** International Convention for the Safety of Life at Sea, sets the standard towards safety of human life at sea.

**STCW:** International convention on standard of training, certification and watchkeeping for seafarers, 1978 (STCW), is a guideline that sets the international minimum requirements for training institutes for marine personnel on seagoing merchant vessels.

**Yara:** Global company, specializing in different areas

**Yara birkeland:** Autonomous vessel, developed by Yara along with various different partners.

# 1 INTRODUCTION

The industry has made several major changes over the past industrial revolutions (IR), where the steam engine started the first 1<sup>th</sup> IR. The first revolution was followed by the second and third IR, that lead to societies moving from agriculture to manufacturing industries. As we now are on the edge to the 4<sup>th</sup> IR, the technical progress during the 3<sup>th</sup> IR have contributed to better living standards but also new challenges. These technical progresses is more widely and different than previous ones as it is argued that this revolution is different from the previous ones due to “...*emerging technologies and broad-based innovation are diffusing much faster and more widely than in previous one and is different in scale, scope and complexity characterized by a fusion of technologies*” (Lundh et al., 2018).

The shipping industry is currently the main global transportation service where the industry accounts for 90% of cargoes transported (Fink et al., 2002; Yang, 2019). Maritime services have always been associated with activities that are conducted in complex ways or risky environments. The shipping industry is also known to be traditional, conservative, and slow-moving since regulatory bodies within the shipping industry, implementing new laws and regulations after major disasters (Lundh et al., 2018). This have resulted in shipping industry to fall behind other industries, when it comes to new technology implementation (IMO, n.d.; MacKinnon et al., 2019; Lundh, 2019). However, the 4<sup>th</sup> IR is not excluding the shipping industry, which now are facing more automation and investments towards computerization (digitalization). The shipping industry has been subjected for an increase in technology during the past decades (Bloor et al., 2000; Conceição et al., 2017; Höivold, 1984). The implication this has had on the crew and how work is performed on board is well researched (Conceição et al., 2017; Lundh & Rydstedt, 2016; Lützhöft, 2004). This research gives evidence of changes in how work is performed on board, e.g. new tasks to perform, traditional tasks performed in different ways and a demand for new knowledge and skills to be able to meet these new demands. Focus of this transition towards a more digitalized and automated way of operations have traditionally been on the operation of the ships bridge (Lundh et al., 2018). The general purpose of the introduction of digital tools have been to enhance a safe and efficient operation of the ships but this change has been also shown to be both counterproductive and inefficient (Lützhöft, 2004). Although less researched, the engine department and engine control room has undergone a similar development as the bridge, including more digital tools and automated processes and monitoring (Lundh et al., 2016). The aim of increasing digitalization in ECR, is to achieve better working conditions and cost-effective services but it has also similar to the bridge brought on more and wider range of challenges (Man et al., 2019). The way engineers are performing their work is on the way to change, where operations of conventional monitoring equipment and systems have been progressively shifted, towards digitized screens and monitoring equipment (Man et al., 2019). While the automation on board is steadily increasing, the engineers requires other skill set, in order to repair or overhaul a faulty machinery. Recently finished research by Lundh & Rydstedt (2016) reports that “*The development may have led to the need for new types of resources for the individual engineer, not the least increased computer skills*” and that “*engineers commonly reported that they have not been provided with any appropriate resources to meet these new demands and requirements*”. This bachelor thesis will therefore, review the marine engineers’ perspective on digitalization and how they think work in the engine department will change and what they see as necessary skills to operate an engine control room in the future.

## **1.1 Purpose**

The purpose of this thesis is to investigate the marine engineers' perspective on digitalization and how they think work in the engine department will change and what they see as necessary skills to operate an engine control room in the future.

## **1.2 Research questions**

1. What are the perspective of the marine engine personnel on digitalization?
2. What do the marine engine personnel see as necessary skills to operate an engine control room in the future?
3. What challenges and opportunities do the engine personnel see with future digitalization of the engine room and control room?

## **1.3 Delimitations**

The delimitations of this study are shipping companies within Sweden and Turkey, Swedish and Turkish marine engineers and technical departments ashore.

## 2 THE DIGITAL AGE IN SHIPPING

The growing presence of automated solutions is not new to us, as automation can be found in various industries such as industrial robots, cars, control systems or even simple regulators reaching all back to the mid-1900 (Carlsson, 1984). As new technologies have been implemented, the technology have shown to be like a double-edged sword which has both problems and benefits. This has been described by Bainbridge four decades ago “...*the irony that one is not by automating necessarily removing the difficulties, and also the possibility that resolving them will require even greater technological ingenuity than does classic automation...*” (Bainbridge, 1983 p.778). However, the picture presented by the industry, covers different responses to the diversity of automation created by this digital age. Clearly, the industries goal is to redefine shipping and allow the industry to transition towards autonomous shipping where some concerns has been raised about operational and management along with security and regulations, of a future vessel (AAWA, 2016).

For several decades, this fast-technological progression within various industries has not excluded the shipping industry, that has also been addressing several technical changes with the focus on increasing the efficiency, safety, crew performance and reduce cost (Lundh, 2010). The way the engineers are performing their work today is on the way to change, where operations of conventional monitoring equipment and systems have been progressively shifted, towards digitized screens and monitoring equipment (Man et al., 2019). These technological developments has been well researched, as reports reveal evidences of different challenges with growing presence of technology and automation in the ECR and ER (Chawla, 2015; Grundevik et al., 2009; Lundh et al., 2011; Man et al., 2018)

Among the results, these technological advantages have already affected majority of the jobs, currently being done by the maritime personnel. Some, more traditional tasks, have been replaced by new technology and are performed in different ways i.e. to more monitoring and administrative duties and new tasks has been added (Lundh, 2010). This alternated working culture on board, where also the crew size has started to decrease and remains small, in connected with new task created by technology such as administrative and automation failures, have resulted in increased workload (Lundh et al., 2016). Also, the necessary skill set of the crew will likely change as well (Lundh et al., 2018). For example, in the report from Lundh (2010, p. 4), she states that “*in addition to this, the automatic control systems call for an increased knowledge about electric-, electronic equipment and control engineering. The contemporary work role of the engine officers has changed from mainly handling mechanical tasks to a role which also entails pronounced operational and surveillance skills*”. This have also been pointed out in Demirel, (2019, p. 8) as “*The automation equipment is mostly based on electronic/electric systems and used by navigation and marine engineering officers and ratings. But the existing education programmes for deck and engine officers do not cover these subjects sufficiently to make them fully understand automated systems*”, which have resulted in poor knowledge in automation and difficulties to problem solve automated failures.

Recently finished research from Grundevik, Lundh, & Wagner (2009) made a comparison between older conventional instruments (hard control) and digital control systems. Their conclusion was that engineers has a better overview when it comes to older conventional instruments, compared to programmable electronic systems (PES) where he also states, that with the transition to soft control systems, several other issues have been found. As ECRs is becoming more automated, more alternative designs of the computers is also included in ECR,



## 2.1 Projects and initiatives developments in the maritime digital age

Other research projects in maritime systems, like MUNIN started back in 2012. Where the project aims to research in maritime autonomous systems and technology potentials, but also verify the concept of autonomous ships (MUNIN, 2016). Moreover, SARUM, has on the other hand focused on legal and liability aspects (SARUM, n.d.). In addition to these research projects, several other finished and ongoing researches such as, Sea Traffic Management (STM) and Kongsberg Maritime Unmanned Navigation through Intelligence in Networks (MUNIN) and Safety and Regulations for European Unmanned Maritime Systems (SARUM). The concept of STM, provides a set of tools that aims to reduce accidents, voyage costs, berthing time, emissions and fuel consumption by 2030, compared to 2015 values (*About Sea Traffic Management - STM – Sea Traffic Management*, n.d.). Kongsberg aims to, developing systems that are designed to integrate humans and machines for merchant marine and offshore vessels (*Automation system, K-Chief - Kongsberg Maritime*, 2020; AAWA, 2016). Further, their automation systems provide more profitable voyages along with the opportunity to optimizing the vessels speed, draft, trim and engine modes during unfavorable sailing conditions to minimize fuel consumption.

## 2.2 Industry initiatives

Following the first discussion, implementing new laws and regulations after major disasters are very common, as regulatory bodies within the shipping industry, is known to be traditional, conservative, and slow-moving. This have resulted in a shipping industry to fall behind other industries (Scott MacKinnon et al., 2019; Lundh, 2018). As a respond to this slow-moving regulatory, shipping companies such as Yara, Stena and Hitachi are trying to break new grounds. An announcement was made by two Norwegian companies YARA and Kongsberg. Together they would start to build their first fully autonomous zero-emission container vessel, equipped with an operating system, capable of making decisions and taking actions without the interference of any officer. According to Yara (Skredderberget, 2018) the goal is to launch the vessel Yara Birkeland by 2020 and will be gradually moved from manned to unmanned within two-year of its operation time.

The first smart ship initiated its first trial voyage in Guangzhou, China in 2017 and was equipped with a marine system, that enables autonomous learning and intelligent operation (Aiswarya, 2017). Moreover, this smart ship is capable of finding the best routes and can also alert the crew for any danger, by analyzing real-time navigation and meteorological data. In another industry initiative was launched by Stena and Hitachi where they revealed the plan for cognitive shipping by integrating analytic-based artificial intelligence (AI) technology with the current fleet of Stena (Hitachi Europe Ltd, 2019). The aim of these transformations is to reduce fuel consumption, operating costs and environmental footprints. With new announcements like this, we can only determine that the industry has already starting to change and thus also the requirement of the crews and their skill sets.

### 3 REGULATORY AND CLASS RESPONSE ON NEW TECHNOLOGY IN THE DIGITAL AGE

The statements above, illustrates that shipping companies are developing different variations of vessels, to explore new ways of transporting goods. Although the concept of autonomous or unmanned vessels will simplify it for most operators and owners, the transition into the digital age will create regulatory and training challenges (MacKinnon et al., 2019).

Since 2018, International Maritime Organization (IMO) has taken the first steps, to address these questions and has commenced the organization i.e. Maritime Safety Committee (MSC) to preliminary set the definitions of Maritime Autonomous Surface ships (MASS), regarding the safety, security, and environmental impacts. The problem is that MASS operated vessels can be operated at one or more degrees of autonomy during a voyage. Therefore, To facilitate this approach, IMO have recently defined the autonomy levels in four degrees of autonomy (IMO,n.d.):

*Degrees of automation:*

*Degree one) ship with automated processes and decision support, where the seafarers are on board for the operation and control of shipboard systems and functions.*

*Degree two) remotely controlled ship with seafarers on board. Seafarers are available on board.*

*Degree three) remotely controlled ship without seafarers on board. There are no seafarers on board.*

*Degree four) fully autonomous ship where decisions are made by the ship itself.*

On the other hand, remote controlled and autonomous ships are required to meet the same standard as existing regulatory. Obviously, type and level of autonomy will also be dependent at this point, and so does the vessels shape, degree of digitalization, size and operational area. Technically this means that the ship still must rely on an engineer to assist in maintenance operations due to “*The shipping industries’ transition into the digital age has a lot of regulatory challenges as the existing maritime rules and regulations as all assume by default that a ship is manned*” (Lundh et al., 2018, p.2).

In addition to IMOs definitions towards *degrees of automation*. Lloyds Register has since 2016, develop new procedures for future guidelines and regulations. Instead of IMOs four degree of autonomous, seven types where made instead, to make sure that different levels of autonomy are emphasized (Henriques, 2017). According to Lloyds Register, the autonomy level is divided into seven categories:

AL 0) Manual – no autonomous function. All action and decision making are performed manually by operators.

AL 1) On-ship decision support. All actions at the ship level are taken by a human operator.

AL 2) On and off-ship decision support All actions at the ship level taken by human operator on board the vessel.

AL 3) ‘Active’ human in the loop Decisions and actions at the ship level are performed autonomously with human supervision.

AL 4) Human on the loop – operator/supervisory Decisions and actions are performed autonomously with human supervision.

AL 5) Fully autonomous Unsupervised or rarely supervised operation where decisions are made and actioned by the system, i.e. impact is at the total ship level.

AL 6) Fully autonomous Unsupervised operation where decisions are made and actioned by the system, i.e. impact is at the total ship level.

The shipping industries transition into the digital age, has therefore raised some concerns about the lack of regulatory support in the area of automation and digitalization which can be shown, as IMO today is at the end of their investigation about functionality and regulatory part of autonomous vessels (IMO, n.d.).

In addition to this, numerous projects of autonomous and unmanned vessels have already been presented by various companies, such as YARA, Kongsberg, Stena Line and Hitachi, that illustrates how slow IMOs movement really is. At the end, the MUNIN project along with SARUM, have already looked at regulations regarding autonomous vessels, where they both have similar conclusion *“Both projects agree that we cannot wait for IMO for a world ratification, since national initiatives allow autonomous vessels on their domestic waters”* (Lundh et al., 2018).

## 4 SKILL SET IN THE DIGITAL AGE

The technological progresses during the 3<sup>rd</sup> IR, has raised questions about what necessary skill set are needed, as we now are on the edge to the 4<sup>th</sup> IR. The increasing computerization with the internet, has slowly changed the labor market by replacing low skilled jobs with automation and computers that is well researched. The industries subjected to large scale automation, resulted in declined work force by two-thirds among factory workers in the United states from 1960 to 2014. As they reported a decline in workforce, they also noticed that productivity increased (Min et al., 2019).

As digitalization and automation increases, necessary skill set will also likely to change as well, creating opportunities for new jobs, as the demand for low skilled jobs decreases (Ahmad & Aladwan, 2015). In 2016, the World Economic Forum (2016) conducted a wide survey on what skills and competencies will be needed across all industries (Table 1). The result from the survey conclude that complex problem solving, are identified as future core competence to use modern equipment. But also, social, process, system skills, cognitive abilities, process skills and critical thinking.

Table 1 Predicted demands for future skills, adapted by future job (World Economic Forum,2016) with permission of Lundh (2018)

Core work-related skills	Scale of skill demand in 2020	Core work-related skills	Growing skill demand
1. Complex problem solving	36 %	1. Cognitive Abilities	52 %
2. Social Skills	19 %	2. Systems Skills	42 %
3. Process Skills	18 %	3. Complex problem solving	40 %
4. Systems Skills	17 %	4. Content Skills	40 %
5. Cognitive Abilities	15 %	5. Process Skills	39 %
6. Recourse Management Skills	13 %	6. Social Skills	37 %
7. Technical Skills	12 %	7. Recourse Management Skills	36 %
8. Content Skills	10 %	8. Technical Skills	33 %
9. Physical Abilities	4 %	9. Physical Abilities	31 %

Given the perspective on land operated industries, little research has also been performed within the shipping by World economic Forum (2016), where several other researches have been made, looking onto competencies and skill sets needed for the 4<sup>th</sup> IR. It was concluded that the shipping industry is facing substantial changes in soft skills such as leadership, lifelong personalized training, management and necessary technical skills to operate modern equipment, that will only become more crucial for the future seafarers (Lundh et al., 2018; MacKinnon et al., 2019). These conclusions have also been acknowledged by IMO which have taken action by incorporating new competencies such as leadership, teamwork and managerial skills to the STCW CODE 2010 (Chawla, 2015).

The statements above in “Projects and initiatives developments in the digital age” illustrate an important conclusion, that existing ships will be replaced by cost-effective and safer newbuilt vessels. As autonomous vessels will start to share waters together with less advanced vessels, some limitations of autonomous shipping are also there.

Research performed by Grundevik et al. (2009) brings up the essential comparison between older conventional instruments (hard control) and digital control systems. Here, the conclusion was that engineers has a better overview when it comes to older conventional instruments, compared to programmable electronic systems (PES) where they also states, that with the transition to soft control systems, several other issues have been found.

One of the problems that this development brought on is that soft control systems, came in two alternated designs. The first design: Consists of computers that uses keyboard with semi-graphic design. The second design: Consists of computers that uses Windows based systems with a standard keyboards and mouse as pointing devices.

Another issue that Grundevik et al. (2009) highlighted, was the soft control displays, where keyboard and trackball control systems had less complicated display architectures, compared to new designed systems. For example, here, they could see a major difference, when it comes to operate different machines (start and stop) or smaller equipment like valves in the engine department (opening and closing). For example, “*For a hard control system, the number of interactive steps required is about 2-3 procedural steps. For the soft control using the function keyboard approach, the engineer’s interaction with the system involves about 4 – 5 interactive steps*”. Even the number of interaction steps for opening a single valve could be as high as 9, before the procedure was complete. Further, the PES control and monitoring systems could reach as high as 12 displays in the control room while soft control monitoring systems could be much as 25-30 displays.

But the most interesting part in this research was the interviews regarding the displays. Here the interviews revealed that “*the displays appeared often cluttered and that one had to shift through too many different displays to diagnose a problem at times. Although the display itself may be relatively easy to find – one has to navigate between all too many displays as complex or intricate system interaction procedures/display structures affecting the engineer’s response time. The more steps required the longer the response time*” (Grundevik et al., 2009, p 5).

From this, we can determine that it actually takes longer to complete a task with more advanced technology. The engineers also added that software could even cause serious damages towards the engine operation such as a blackout if the program had to many bugs or malfunctions along with lack of emergency control functions in software interfaces.

From these researchers, we can clearly see that this can cause problems among the engineers. The familiarization has therefore, been inconsistent when it comes to implementation of new technology on board vessels (Grundevik et al., 2009; AAWA, 2016) and the gap between todays skill set and the future seafarer is and are possibly considerable larger than expected (MacKinnon et al., 2019).

As the industry is trying to figure out the skills and competencies for the future, some actions have been taken by IMO. It has also been shown that new technology implementation creates

new challenges i.e. lack standardization and insufficient knowledge in understanding of automation, which will make this transition difficult for the engine personnel. The educations today follow the minimum criteria of STCW, which have also been pointed out by several researches, where education but also IMO and STCW have lacked behind and stayed more traditional compared to the needs of the industry. This have resulted in several challenges and difficulties regarding the operation of ECR and the operators (Demirel, 2019; Costa, 2018; Man et al., 2018). Therefore, an awareness towards this part of the domain needs to be intensified, despite the fact that similar technical developments as to the bridge has occurred there (Grunde vik et al., 2009; Lundh et al., 2018; AAWA, 2016).

## **5 METHOD**

This report is based on a qualitative research on the ongoing digitalization in maritime control rooms. The qualitative method strategy was mainly chosen due to the explorative nature of the study. This strategy also provides the best option and are more appropriate to gather empirical data for the chosen research questions, as these research questions is related on marine engineers' experiences and point of view is. The semi-constructed interview strategy has allowed the authors to acquire answers to three themes (see appendix A, B and C with consent) developed in relation to the research questions during the start of the project. The interview data was later on analyzed and provided the necessary result to answers the research questions of the thesis.

### **5.1 Population**

This report includes eight participants where six are Swedish and two Turkish nationality with and average age of 45 years old. The youngest among the participants were 29 and the oldest 58 years old with a standard deviation of 11,4. The rank of participant in this thesis was one second engineer, three first engineers and three chief engineers.

### **5.2 Arrangement**

The chosen interview method was a semi structured interview, due to this method was the most suitable strategy, to acquire data to three open ended themes created at the beginning of this thesis. Due to the circumstances of COVID-19, the interview was handled over by phone and if anyone want to arrange similar interviews and themes in the future, use the guide and questions in Appendix A, B and C.

Also, to be noticed. Before the interview, the participants where informed about the ethical rules about the project i.e. that the interview would be recorded and the data would be stored and used, and that the data would only be accessible by personnel involved in this project which is the authors and mentor (see appendix A).

## **5.3 Gaining access**

The access to engine officers currently working in the industry was mainly done by contacting individual shipping companies. The contacts within the shipping companies later helped us locate people with the relevant experience and expertise within the engine department to participate in the interview also called the subjective selection (Denscombe & Larson, 2018). According to Descombe and Larson (2018) subjective selection is best when searching for information by focusing on a relatively small group of people who have been deliberately selected with their relevance to the subject or theory which is been studied but also with the experience and expertise they possess on the subject (Denscombe & Larson, 2018).

## **5.4 Interviews**

To create an understanding of various technical solutions, this report has investigated the potentials and challenges with the fast progressing digitalization currently ongoing. The investigation was based on interviews, generated from six Swedish and two Turkish marine engineers', currently working as engine officers within the Swedish and Turkish fleet. To reach all participants during the circumstances of covid-19, first an email conversation was established, to send over all the questions we wanted to get answers on. This to make sure that all participants could be able to prepare them self for the interview over the phone. The duration of the interviews was 30 to 60 min, depending on the experience, age and time due to most of them was working on board.

## **5.5 Ethical consideration**

Qualitative researches that include data from real people need to consider the ethical review to not harm or risk the well-being of percipient of the study. According to Descombe & Larson (2018), there are four main principles in research ethical codes.

“The four ethical principles” Descombe & Larson (2018).

- Protect the interest of participants.
- Ensure that the participants are voluntary and based on informed consent.
- Avoid false pretenses and pursuing scientific integrity.
- Comply with the national legislation and laws.

Taking into consideration the ethical principles the authors have informed the participant before the interview about the purpose of the study and how the data would be stored, used and published moreover that the participants were going to be anonymous to not be affected by the sensitive material. The participants were also assured their right to withdraw from the study without any reason at any time. To follow the ethical principles and ensure the rights of the authors and the participants a written consent was signed before the interview.

## 5.6 Analysis

The primary data gathered from the interviews was transcribed, coded and stored. The analysis of the data was through a thematic analysis and done in several steps according to Braun & Clarke (2006).

Step 1: Familiarization of data which means analyzing the data in an active way with repeated times to search meanings and pattern.

Step 2: Coding extracts which means the patterns and meanings extracted from the raw data is being coded. This step is when the similar patterns and meanings is gathered together.

Step 3: searching for themes is the step when different codes is being analyzed again to form potential themes, sub-themes and main themes.

Step 4: missed codes are being assessed again to form new themes also the validity of the formed themes is assessed in relation to the raw data and whether these themes is accurately reflecting the meaning evident in the data set.

Step 5: in this step the themes is named accordingly to the meaning the themes refer to.

## 6 RESULT

Based on research questions the result is divided into three parts, questions presented are the followed. The first theme presents what kind of perspective marine engineers have about the ongoing digitalization in the engine and control room. Second part presents what do marine engineers see as necessary skill to operate an engine and control room in the future, followed last with what opportunities and challenges they see with future digitalization of the engine and control room.

### 6.1 What are the perspective of the marine engine personnel on digitalization?

The result shows that the engineers today are partly satisfied with the current digitalization as it has together with the automation eased their daily jobs by making it more efficient and comfortable. However, besides satisfaction the results also show that current engineers do not want any further progression implemented on board as the technology has shown to be like a double-edged sword with several difficulties. Apart from the advantages these technologies have implicated higher involvement of electronics and software-controlled systems within the ECR which have resulted in difficulties for the engineers to troubleshooting, identify and fix failures.

#### 6.1.1 How will digitalization change the ER/ECR?

The first question asked to the respondent was which changes they had experienced with digitalization and how these changes had affected them and their working environment on board. From the responses, it emerged that digitalization has given rise to many changes foremost the work performance on board which have resulted in decreased workload and a shift from heavy intensive work to monitoring and administrative tasks. Another apparent change with digitalization was the increasing presence of computerization and automation which reduced the need for human intervention within the ER as manual monitoring and operation of equipment i.e. pumps, gauges, and analog switches were enabled to remotely operate and execute in front of a computer within the ECR. From the responses, we can see that the engineers are satisfied with the current level of digitalization as it has allowed them to be more comfortable on board with the reduction of heavy intensive work but also because digitalization has integrated and connected all systems on board for higher efficiency.

*"/.../ Digitization varies from ship to ship due to many different reasons such as ship types, operational needs, year of shipbuilding, etc. The age ranges of naval merchant ships are wide, although recently refurbished fleets have increased. However, the reduction in the need for manpower along with the automation systems on board can be shown as the biggest change.”  
- First engineer*

*"/.../ Mainly from 90% hands on overview-regulation-control work to 90 % computerized work  
(i.e administration work)” - Chief engineer*

## 6.1.2 Strengths with digitalization

According to the respondents, there are several strengths and difficulties with digitalization and automation. Results points out that the work has become more comfortable with the reduction of workload. Besides decreased workload, the efficiency has also increased as the operators do not need to go out to the ER for manual in place surveillance and operation of i.e. gauges, manual switches, and valves for machinery as automation has enabled to remotely operate and execute these systems in front of a computer within the ECR. Beside remote operation, advanced automation has also made it harder to forget machinery details, for example, when starting the main engine i.e. cooling, lube-oil systems. The system on board has become smarter where a push of a button executes commands in a sequence that starts all the necessary systems. Digitalization has demonstrated to be greatly favorable as it has also made it possible for more measurement points with sensors where a large amount of machinery data has become easier and fast accessible by monitors within the ER by this also increased the SA. The machinery data have also shown other advantages besides SA where it has made it possible to access key information for decision making and detect faults earlier and enabled to plan maintenance plans further ahead to avoid breakdowns and reduce maintenance-related costs.

*“/.../With schematics can we see if it is 300 degrees or 400 degrees if the temperature reaches a certain degree that it will alarm here. And what happened, with technology and further development it has become more comfortable and will be more comfortable (less physical work and easier tasks), why yes because we have now a system which all the time alerts us” – Second Engineer*

*“/.../Yes, that question I do not know if I can answer, these ships are of course not that digitized. But what to answer to that, i can compare it to previous ships were there have not been any readings at all. Ahh what can I say, digitalization itself I do not know if it has affected much, but on in its best times that you have better information, better and easy access would I like to say” – Chief engineer*

## 6.1.3 Difficulties with digitalization

From the result, we can see that digitalization has shown to have several strengths, yet the respondents were also clear to point out several difficulties as digitalization has shown to be a double-edged sword. As mentioned before digitalization has granted access to a large amount of machinery data with alarm functions on monitors. The respondents further explain, during normal operating conditions with plenty of free time the information provided is very helpful however during abnormal times with system complications, the monitoring system provides excessive and uncomprehensive information often unrelated to the failure. During these times is it essential to take fast decisions and action to prevent further failures or in worst cases accidents which this excessive information, unfortunately, makes it harder find. Alarms, excessive unrelated information (overload of information), and stress for not knowing the problem taking into account the operators need to take their time which they do not have to sift through the data which can be a vital factor for accidents.

*“/.../ O yes if it is in hurry then you have to sift through the information and then, if you have a lot of time available you have to search in the pieces of information but if you are in hurry and do not have time then it’s a challenge/weakness. But if you have a lot of time it’s a strength like I said it’s a bit contradictory” – Chief Engineer*

Another challenge with the monitoring equipment besides the excessive information have been the interface. Today the monitoring equipment is made by different manufacturers that have their unique interface. According to the respondents, the interfaces are not user friendly designed for the end-users, contains a substantial amount of abbreviation often not correctly spelled and consist of too many menus which is also negatively affecting the engineers when they need to access the information they seek.

*“/.../One challenge which I have noticed. I think/feel that all is not user friendly, imagine yourself we have different menus to different, there is one menu for the boiler another menu for the inert gas-boiler, and one menu for the fire-alarm system and they are all different structured/build. It is so that all are different and also partly so are they not easy to understand it is a challenge to get it more user friendly”- Chief Engineer*

Beside information overload and interface challenges, other difficulties were also distressed by the respondents. Today’s new vessels have become more advanced and complex were nearly all systems have become controlled by a software-based computerized system that has enabled to start and execute system by a push of a button i.e. starting the main engine and boiler. By giving the system the command, it executes all the necessary systems in sequence to operate the desired machinery without further intervention by the engineers. However, as these sequences are highly dependent on sensors and software when the sensors fail, it would crash the automation. This have also given arise for another challenge which is lack of redundancy where the engineers cannot always disconnect automation and go over to manual operation which can also lead and result to disasters.

*“/.../In case it does work then it Is good but when you have a problem then you have to operate it manually, then it is not so pleasant/enjoyable anymore, because maybe you can not, then you have to. If you do not know how to disconnect the automated system entirely and operate manually then it is a bit hard then it is suddenly manual right now and maybe it gives alarm because it is manually now or maybe something else that you have not chosen but the computer has in the software which has told the system this is the way to go” – Chief engineer*

With highly digitalized vessels the ER and ECR have become more advanced and complex which have resulted in a shift of mechanical components to digitized i.e. buttons and a manual switch for startups and gauges for follow up are today more accessible on monitors both in the ER and ECR. This shift towards a more digitized operation has enabled the engineers to follow up and quickly engage with the machinery almost in all places on board. As this change has made the work more efficient, it has also raised different challenges such as un-ergonomically designed monitors often too small to see and engage but moreover is also too sensitive to wet or dirty fingers which have made it extra difficult to execute different tasks. another major challenge with highly digitized vessels which concerns have been raised is the shift towards more advanced system and electronics which have made it extra difficult to troubleshoot, find

and fix the problems. As these systems are executed by software control which is running in the background.

*“/.../Like as was saying before it is a weakness when the system does not work, the troubleshooting process becomes significantly harder when you do not really have any clue what is happening in the background of the digitized system. When it comes to monitoring equipment you need to have a certain skepticism. Can all the information/values be trusted which you get and is it any legitimate/trustworthy. The more digitized control room it becomes more exposed if there are more a lot of automated systems then it can also mess up due to a faulty sensor, faulty software or something similar”- First engineer*

#### **6.1.4 Is the engineers satisfied with the digitalization?**

The analysis shows that the engineers today are satisfied with the current digitalization as mentioned before it has made it more comfortable for them in their daily lives on board. however, the respondents have also shown concerns with the technology as digitalization has made it possible for less intervention in the ER as entire machinery equipment and systems can now be remotely operated within the ECR. With this, the respondents have suggested that new vessels are entirely changing the fundamental work on board where the engineers in the future with the current progress towards full automation will result in a more ECR operator. This development will result in different risks where the engineers will forget the engine room fundamental and become more absent from the reality of the machinery. Secondly dangers with lack and failure of redundancy where the engineers will not always have the chance to change over to manual operation and where more advanced automation lead to less capability of manual operation, therefore, the respondent have pointed out the importance of a balance between automation and conventional equipment.

*“/.../No at the moment I do not want any more, it is enough with what we have. But this i cannot control it has with the generations to do which comes after and what they become familiar with. It cannot be that we control and operate everything where we lose reality. Then, that you cannot handle it, that you cannot handle it manually also[...] I think it will be good only good, just so you do not lose reality without you can grab what is happening and that you can operate manually also if something fail. It cannot be that an computer is controlling/drive an engine and we cannot interfere and get away and are not able to do anything. We must be able to emergency-drive things, if we know it is okay of course”- First engineer*

Secondary failure of automation is also creating several difficulties where the engineers' knowledge in automation today is lacking behind and creates difficulties understanding, troubleshooting, and fixing electrical problems. The result has shown automation failures today create more work for the engineers which have resulted in different challenges such as. higher downtime, insufficient crew members for the extra added work due to automation failure.

*/.../ Yes, I can explain it like this, we are coming from brazil to turkey and our autopilot fails and what happens after, yes we got into manual steering. But what is the meaning of manual steering. Yes that one person is standing all the time behind the steering wheel, always looking sea chart why, because of the conditions the ship may alter its course and on good and bad can also the person behind the wheel make mistakes which may also alter the course. Let me tell you honestly, we came like a snake till we arrived at our destination. We did not have any problem and got the ship to the port. But what happened we prolonged our journey, we lost*

*time after all the ship is competing with time, one or two days every day is money for the ship”  
- Second engineer*

## **6.2 What do the marine engine personnel see as necessary skills to operate an engine control room in the future?**

The result is showcasing that marine engineer today experience challenges with advanced digitalization i.e. software and automation failures. New vessels today have become too advanced and complex which have resulted in outpacing the knowledge and experience of marine engineers. This progress has implied that the engineers today do not possess the knowledge and understanding of the current new systems on board which have present challenges in troubleshooting, identifying, and fixing problems. It has been made clear from the responses that technology has outpaced the maritime educations and engineers' knowledge which has implied as stated challenges, however as the technology is still progressing the educations needs to catch up to the demands of the market. The results highlight future educations need to be focused on electrics, electronics, and advanced automation as these become the norm on board vessels where the conventional equipment is at the moment being replaced.

### **6.2.1 How will digitalization affect marine engineers in the future?**

According to the respondents, the current technological development which has been made with digitalization has affected the engineers in different ways. As stated earlier the ECR and ER have become to be presented in more software and electronics which have become too advanced, complex and less transparent. This development has resulted in where today is it not enough for the engineers to just change faulty mechanical components and parts anymore as it has become more software problems rather than mechanical problems. The result shows that the technology is rapidly shifting where the ER and ECR are becoming more digitalized and where conventional equipment have become lesser. According to the respondents, this shift has started demands for new engineers i.e. an expert in automation, electronics and software however it is also noted that marine engineers today need to become more experienced with i.e. computer skills and knowledge how automation works as these changes have made it difficult to troubleshoot, find and mend failures on board. The results also suggest that the work within the engine department will become in more monitoring where the maintenance will be handled by shore personnel which has become specialists within the different systems. This has also raised some concerns by the respondents which exhibit that future marine engineers may not be fitted for the work on board as the systems become too complex and advanced which requires a different kind of specialist.

*“/.../Digitalization is demanding new operators/engineers, today it is not enough to just change mechanical parts anymore. The engineers needs a better computer skills as it comes more and more software faults than mechanical faults. Eventually I think service and repairs will eventually overall be taken over by the providers/manufacturere. All systems as the equipments’ becomes more and more complicated and we engineers are not sufficiently/enough involved on how automation for the system are constructed” - First engineer*

*/.../ Knowledge and experience reduce the adaptation process together. Machine officers who have developed themselves on automation and electronics will be successful in this process, but*

*those who do not pursue this follow-up will be gradually eliminated from the sea” – First engineer*

## **6.2.2 New competency for marine engineers**

The shipping industry has in recent years started to rapidly change where the new vessels have become more advanced and complex which have meant that conventional equipment and system have shifted over to digitized. The industry is moving forward to autonomous vessels where the need for human intervention is becoming less needed and instead shifted to more monitoring within the engine department which has also been pointed out by the respondents. The respondents feel that work on board will only convey to more monitoring in the future as the maintenance will be handled by shore specialists. However, until the autonomous vessel becomes the norm the engineers who are lacking behind in knowledge and expertise in handling advanced digitalized as these have resulted in major difficulties as stated before in troubleshooting, identifying, and fixing electronic failures. The result has raised several challenges to come where maritime education today is lacking behind. According to the respondents, the education needs to catch up with the current market demands which implicate more focus on electric, electronics, and automation which today yields difficult challenges but also to enable the engineers to stay relevant and allow them to perform their jobs in the future.

*“/.../NO, you do not have the knowledge anymore, that is also what we have said/told when we were on nautical college and told them it is not calculation you should do and focus on but focus on troubleshooting. More troubleshooting and are more at an electrical workshop, we/they have now talked about the nautical colleges in twenty to thirty years that there is a need for more troubleshooting” - First Engineer*

*“/.../Electronics, they should learn electronics, they should add this course. We got educated on electric and electronics but I do not know if it is the same for you but it was not much. Maybe it has something to do without the education system but I do not know that, anyway I have been educated on electric and electronics” - Second Engineer*

## **6.3 What challenges and opportunities do the engine personnel see with future digitalization of the engine room and engine control room?**

A challenge that the respondents have indicated is the urgent need for an standardization in the ECR. Without standardization the engineers today feel lost between equipment made by different manufacturers with their unique interface, besides standardization, the interface also needs to be user-friendly designed for the end-users on board which have also been proposed. This together will make it possible for the engineers to sign-on other ships within the fleet without the need to familiarization of new machinery. The respondents also indicate a big challenge with regulations that are today difficult to follow where the engineers feel that the regulations are confusing and difficult to interpret and follow. As the shipping industry is moving forward with the technology the engineers emphasize a review of regulation to make them clear and more straight forward which will ease and enable the maritime workers to follow. A possible review of regulations will also make the transition clearer towards a highly digitized maritime industry.

### **6.3.1 System and interface standardization**

The shipping industry has been a hot subject these past decades where several debates have been brought up to discuss and find smart solutions to meet international environmental goals. As a result of this, the bridge has been heavily focused on where different standardization has been made for the systems and equipment on board related to the navigation, safety, and cargo. However, as the bridge control has been on focus it has resulted in where the engine department has been forgotten and left in the background which has lead to several difficulties for the engineers on board. The ECR consists of different equipment necessary for propulsion, these equipment and systems are today made by the different manufacturer i.e. Kongsberg, Wärtsilla, and Alfa Laval. Due to non-standardization, the systems in ECR have ended with different unique interfaces for each system which have brought up difficulties such as separate learning for each interface system. Moreover, as ships, today tend to differentiate due to operation style it has also made it challenging for the engineers to sign on other ships within the fleet as they become beginner due to non-standardization. According to the respondents' circumstances like these result in poor SA for the engineers but also lead to where the work gets challenging as the engineers need to learn the interfaces together as they operating the vessel. The result shows that standardization in ECR today is needed as this will make it easier for the engineers to operate the vessels but also make it easier for them to sign on other ships. The standardization will also make the interfaces more clear which respondents have shown that they feel that the interface today contains too many menus which makes it harder for them to find the information they seek but also because it makes it easier for them to get lost between the information.

*“/.../One big and quite basic development should (in my opinion) be that the ECRs are made standardized, i.e same way as on most of the bridges”- Chief Engineer*

*/.../One challenge which I have noticed. I think/feel that all is not user friendly, imagine yourself we have different menus to different, there is one menu for the boiler another menu for the inert gas-boiler, and one menu for the fire-alarm system and they are all different structured/build. It is so that all are different and also partly so are they not easy to understand it is a challenge to get it more user friendly” – Chief Engineer*

### 6.3.2 Restrictions for a good digitalization

Digitalization has shown to be favorable among the marine engineers as it has made the work on board more comfortable. However, as the technology has shown great potential for the future specific concerns have been raised which are currently limiting the application and use of technology. The respondents have raised concerns about the quality of components i.e. sensors and automated components and software which digitalization is highly dependent on. Global trade parts are today manufactured and software programmed in different countries where the quality highly depends on the knowledge and expertise, but as free trade has allowed the shipping companies to acquire cheap parts and programs it has resulted in limiting the extent of use of digitalization. The responses suggest that parts today tend to break down more often which results in losing automation hence creating more work on board. As mentioned earlier failure in automation also creates difficulties in repairing electronic faults. While digitalization is progressing and the ECR becoming more dependent on electronics the respondents have also pointed out because of the unreliability of parts such as sensors due to poor quality the engineers today do not trust in automation hence a good quality is lost.

*“/.../Yes I think so, digitalization is very good when it works but on a ship, things tend to break apart, and then often is it very hard to understand what the fault is and then fix the problem. One classic example is the level measurement of tanks, you can never trust them. If a ship is going to be fully digitized and automated then you need to be able to trust the system and what you see on a screen is actually the real value. Unfortunately, this is not the case, i think also the knowledge where the ships are built example China where the knowledge is still bad to get a good digitalized and automated ship” – First engineer*

*“/.../In my opinion- and this is my main sum up conclusion from all engine room operation on new vessels- 95 % of all problems we face on board are related to the control- and alarm systems- I.e that the systems make wrong judgements and wrong corrections! We rarely face any mechanical problems on board, but still a lot of sudden shut downs due to faulty sensors and signals from the systems” – Chief engineer*

To maximize the usability of digitalization and increase the trust in automation the respondents have suggested that there is a need for an international requirement on quality of parts and software programs. Furthermore, on redundancy where the engineers may always have the option to disconnect automated system to run in manual. As the vessels today are built-in cheap labor countries with poor knowledge, expertise in automation, and digitalization a requirement would assure a good standard for the use of the system on board.

### 6.3.3 Regulations

Technical development is requiring the regulatory organization to keep up with the progression, as the shipping industry has now started to shift into a more digitalized industry. Past decades have implicated several changes in rules for working on board vessels however as the technology has given rise to new professional i.e. ETO, Electronic engineer, hydraulic engineer plc, and computer engineers it is requiring the regulatory organizations to change and adapt the ranks for the current demand in the market. The result showcases and implies that engineers today experiences, trough difficulties in interpreting and following maritime rules and laws as the current regulations today are to diffuse and hard to follow, therefore there is a need for improvement where the regulations need to be more clear and straight forward. This review of regulation will be essential for the engineers in order to understand and follow easier but more so to simplify the transitioning into a more digitalized industry.

*“/.../I think that the rules for working on a vessel has been changed so much that also the ranks on board must be changed and adopted to the current demands. Basically more experts are needed today (ETO, electronic electrician, hydraulic engineer, PLC engineer, computer engineer etc” – Chief engineer*

*“/.../ With clear regulations, it will, of course, be easier to put a standardization as shipping is an international market all countries should have similar regulations. For example, digitized logbooks or similar things are approved everywhere however still today's history over machinery such as temperature are more important in paper format than digitized” – First engineer*

## 7 DISCUSSION

The progression of digitalization within the shipping industry has within the recent decade taken momentum and is currently at the stage where the industry is transitioning towards autonomous shipping. Digitalization has been affecting the work in the engine department since it was introduced. Previous research has given evidence of how the crew has been affected by the introduction of new technology and been forced to adapt (Lundh, 2010). The results in this thesis align with these previous results and confirms that the work is continuously changing and affecting the work of the crew. The development and these changes are by the subjects regarded as partly positive but not entirely. A study performed some years ago investigating the changes in work on board in the engine room stated “The content of the work has changed, staffing has been reduced, new tasks are being added but the organization of the crew and the design of the workplace remains unaltered.” (Lundh, et al 2016 p.1). The result from the interviews performed confirmed that this is still the case and adds further an increase of technical complexity into the situation in the ER and ECR.

The results in this thesis high-light both positive and negative attributes which the technology provides and was by the subjects resembled as a double-edged sword. The result from interview shows that on the positive side, digitalization has implied that the day-to-day work and monitoring of the machinery has become more efficient and implied a reduced workload. This shift towards higher computerization has also implied changes in work performance where intensive work in ER has changed to ECR monitoring and administrative duties. This is a change in attitudes towards the increase of administrative work compared to research results performed earlier were the increased administration was regarded as an increased workload and a drift away from the core work of an engineer (Lundh et al 2016; Lundh, 2010). The increasing computerization has also enabled to operate machinery and systems, i.e. the main engine which was prior operated through analogue switches, button, and gouges, now it is operated by using monitors. This transition from analogous equipment to digital has been describes as less favorable, as the immediate access to information and information sharing amongst the engine crew members is partly lost in the digital interface as that information is only available for the operator in front of the screen (Lundh et al., 2011). Another advancement also raised from the result is the capability of acquiring more machinery information through more sensors and measurement points.

However, as more information has been seen as advancement and positive attribute it has also raised several difficulties where previous research has given evidence for (Chawla, 2015). A study conducted two years ago on the growing presence of information technology highlights several difficulties and negative impacts on the operators (Man et al., 2018). The information on monitoring is today scattered on different specific monitors by the individual manufacturer i.e. Alfa Laval for boiler, Wätsilla for the main engine, and Kongsberg for the monitoring equipment. As this information is available on different screens it creates struggles where the operators need to read, memorize, and compare the different data to be analyzed which apparently remains as a problem (Lundh et al., 2011). Another difficulty which was brought up by the respondents, which align with previous result, is that the operators today are drowned in too much information which is not easily accessible but also time-consuming to retrieve information as mentioned (Lundh et al., 2011). This information and a large number of alarms during failures often where unrelated alarm to the fault have also resulted in cognitive overload which may also result in loss of situational awareness (SA) (Chawla, 2015).

The past few years have involved several studies where future competencies and skill sets for shipping industry and the marine engineers have been investigated. These studies point out that soft skills like leadership, personalized lifelong training, management, and technical skills necessary to use modern equipment as important (Lundh et al., 2018; MacKinnon et al., 2019). The result from the interviews was partly aligned with these results as the respondents had a focus on technical skills. Knowledge in troubleshooting, electric, electronics, and understanding of automation was pointed out as challenging, which also other research give evidence of (Demirel, 2019). However as future needed skill set and competencies is partly assumed as we try to predict the future, indicates that more research in this field is needed. The result from the interviews gave evidence that there are major challenges ahead, partly due to the current knowledge of automation is lagging behind. This have resulted in today's engineers experiences difficulties to adapt toward the work demands on board. This issue is also described in earlier research highlighting the problem of automation creating a more complex and less transparent environment for the engineers to manage (Lundh, 2010; Lundh et al., 2016). The respondents also indicates that the current education systems and the minimum STCW requirements need to be reevaluated, as today's education in electric, electronic and automation is not sufficiently to be able to meet the market demand. This has also been given attention in previous research; "The automation equipment is mostly based on electronic and electric systems and used by navigation and marine engineering officers and ratings. But the existing education programs for deck and engine officers do not cover these subjects sufficiently to make them fully understand automated systems." (Demirel, 2019 p.8). These gaps in competencies and skills have today made the operation on board difficult as the ECR has become present with more digitalized systems. As the industry is moving forward to become more advanced and complex the current education system also needs to catch up to the demands .

It is known that new technology requires new knowledge and competencies. Technologies have been continuously implemented without interference both in the ER and ECR. However, as new technology has been employed the education have remained the same and mostly the engineers' competencies as well which can be seen with the increasing automation on board (Demirel, 2019). The introduction of automation resulted in reducing the workload on board by giving better control in engine activities it has also simplified record-keeping of alarm and control unit and by this changed how work is carried out. However, as the automation had made it more comfortable on board it also resulted in creating more work with automated failures. According to a study as vessels become more automated advanced it also requires new and different knowledge i.e. electric, electronic, and understanding of automation as more and new systems are being introduced (Lundh, 2010). The result from the interviews shows that there is a lack of knowledge today among the marine engineers which have resulted in difficulties in troubleshooting, identifying, and mending electronic and automated failures which are supported in other research (Demirel, 2019).

The result from the interviews raises concerns to where the biggest challenge in connection with the increasing presence of digitalization is within the future ECR. Several other studies have also been made within the past years where surveys on marine engineers have been conducted and where standardization has been heavily discussed (Costa, 2018; Man et al., 2018, 2019). The results conclude that the ECR is in dire need of standardization as it has to lead to many challenges among increasing the familiarization time on board where this also makes it harder to sign on other ships as the personnel becomes beginner again. Demirel's report made last year also conclude to this "The result of non-standardized controls and displays is an increase in the amount of training needed to make a seafarer familiar with, and effective in, the

use of the equipment.” (Demirel, 2019 p.4). These conclusions also concur with the result from the interviews. As the progression with digitalization is still ongoing standardization will only become more important for the future as different digitized equipment is still being employed to the ECR. Previous reports and result from the interview also highlight possibilities and advantages if a standardization would be achieved example to this is where information becomes more apparent and user friendlier i.e. a better information overview towards the end user and makes it easier to engineers to become familiar and more effective in the use of the equipment (Demirel, 2019). The necessary learning curve would most likely also flatten when the engineers are faced with new technology which could make work more efficient and safe.

## **7.1 Method discussion**

The results in this thesis rests on qualitative data. It is argued that validity as a qualitative concept is not valid and alternative criteria needs to be used (Eneroth, 1984; Stenbacka, 2001; Corbin and Strauss, 2008). Alternative ways to assess the quality of the research are, as suggested by these researchers, for interviews a non-forcing strategy with strategically chosen participants and a transparent and clear description of how the research was performed and analyzed. The qualitative method has shown to be more suitable due to a limited amount of data and research available today on digitalization within the engine control room. As a result of this, the method has shown to be more favorable as it has enabled the authors to use semi-structured interviews which have made it possible to acquire the most relevant data from people with hands-on experience and knowledge with the current technological changes and progression on board. With this interview strategy together with selected open-ended themes, the strategy has also helped to bring forward freely the respondents' feelings and thought on the subjects without any influence by the authors. The interview was followed by three open-ended themes to acquire as much relevant and crucial data as possible without the concerning of time shortage.

At the beginning of the research, the purpose of the study was meant to find what marine engineers' thought was on digitalization within the Swedish fleet. however, as the research started, and interviews began several concerns arose which forced the study to stretch the preset boundaries and delimitations. One concern was the global COVID-19 epidemic spreading to Europe which this concern was later approved. The spread of the epidemic had negatively affected the interview process as several respondents choose to not participate, furthermore this circumstantial resulted in where the researches choose not to follow through with the delimitation of the research group as sufficiently partakers could not be found. The research was conducted with six Swedish and two Turkish marine engineers and due to the crisis the data gathering process was flexibly handled, namely where four interviews were performed by phone and three by writing to the same themes used during the interviews.

Another concern with the interview strategy was the concerns regarding the limited time to perform and conduct interviews, transliteration, and to process and analyze the data to create and obtain themes for respective research questions. This concern was later on to be proven wrong as the interviews went smoothly and the researchers were able to process and prepare the specific themes in time. This was only achieved due to the interviews being done by phone as this allowed the authors to save and fully utilize the time which otherwise was lost for transportation. With the consideration of the global pandemic, the author in this report feels

satisfied with the outcome of the research however how small the research group may as be, this is due to the outcome of highly interesting and intriguing results obtained.

### **7.1.1 Reliability**

The traditional definition of reliability stems from the experimental tradition where researcher and methods are regarded as separated from each other (Stenbacka, 2001). This implies using reliability in the context of qualitative studies are usually misleading and a thorough description of the process, analysis and execution of the project and data collection is preferred (Stenbacka,2001). This will make it possible so that the research can be made again by others with similar results with the provided interview guides and consent as appendices shown in appendix A, B and C. However, as this is qualitative research several issues need to be considered where the result from the interviews can be affected by the authors' personal feelings or point of view. Therefore, After the interview, the data was thoroughly analysed by one author where several themes were created for each respective research question accordingly to Braun & Clarke (2006). After completion of the analysis the data was thoroughly reviewed again by the second author this is to assure that the author who analyzed the data was not affecting or influencing the data with his ideas, hence assuring the reliability and credibility of the result by minimizing the chance of the reliability to be weakened. According to Descombe & Larsson (2018) there is also concern relating to same research being done by other researchers “If someone else does the research, would he or she get the same results and come to the same conclusion?”, the authors of this study has recognized this concern as the result partially concur with previous reports it may not be possible to obtain same results for research conducted in the future. As there is a slight possibility that new amendments, rules, education systems, operating systems, or even the questions, etc. may take another direction since this report was completed.

## **8 CONCLUSION**

This study has investigated what perspective the marine engineers have on digitalization today, what skill set will be needed for the future, and what challenges and opportunities they see the technology will provide in the future. The result of the interviews shows that the marine engineers today are satisfied with the current digitalization. However, this thesis presents data that shows that digitalization is an area with several opportunities and difficulties. Among the opportunities, the result shows that the work on board has become more comfortable and efficient with the shift from traditional engine work to more monitoring and administrative duties. However, as digitalization has eased the work it has also raised difficulties and challenges as automation failures today, contribute to an increased workload on board where the current marine engineer experiences difficulties in troubleshooting, finding and fixing automation-related failures and with more electric and electronic it has become too advanced, complex and less transparent for the marine engineers' knowledge and expertise. As the vessels will become more advanced and complex i.e. more advanced electrical and electronics the results from the interviews show that the adaption of marine engineers towards new technology has come to an end. Hence the current education systems need to change and start to follow the technological progression and implementing more courses in electric, electronic and advanced automation to prepare future seafarers' understanding of these subjects to stay relevant in the future market.

The result also shows that marine engineers today see challenges with system interfaces which have been heavily discussed within past years, however as this is seen as a challenge it is also seen as a big potential for the future if a standardization would be achieved. As the standardization would enable the work to become easier and more efficient furthermore making it easier to sign on other ships within the fleets without the need to learn new systems. The shipping industry is moving forward to autonomous shipping we the industry is preparing the future vessels to become crewless however until then. This report highlights several difficulties and challenges which need to be overcome in order for a smooth transitioning within the industry.

### **8.1 Further research**

It would be interesting if future researchers, investigate on a larger scale to find the gaps of the competence and education system. For example, could be to investigate the education system and compared to new technology, that is implemented today and in the future, to see that gaps between new graduated operators' knowledge compared to new technology. Also, when an accident is caused by a malfunction of automated system, who would be responsible for that accident. Would it be the shipping company, the manufacturer or perhaps the person behind the screen or on board. Either options are for sure interesting to really get the big picture of what needs to be done.

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# APPENDICES

## Appendix A **CHALMERS**

Hello!

We are two students Mustafa Gundogdu and Oscar Josefsson from Chalmers University of Technology at the Department of mechanics and Maritime sciences. We are currently doing a bachelor thesis in the marine engineering program and are writing our thesis on Digitalization in the engine control room. The purpose of our thesis is to investigate what Swedish engine officers and shipowners think/thoughts are about the current ongoing digitalization, therefore, we would appreciate it if you or any of your colleagues would be willing to partake in an interview with us. The interview is semi-structured and will be oriented around three themes. We are estimating that the interview will take about 30-50 minutes.

Before we ask for your participation, we want to inform you about the ethical rules apply in the project.

1. Your participation is voluntary and you have the opportunity at any time during the course of the project to cancel your participation. You do not need to give any reason for this. Should you choose to cancel your participation, the data linked to you will be removed and the material destroyed.
2. You are guaranteed anonymity in the project and data that will be presented will be reported without connection to the vessel, person or shipping company. Your data will be coded and the code key will be stored so that only the researchers have access to this data. This coding is used to make it possible to contact the test subject for any supplementary information and to be able to identify that the right material is destroyed if you choose to skip the study.
3. Data presented in the project will be reported in reports, seminars, and conferences. If you wish, you have the opportunity to read and approve the material before it is published.

### **CHALMERS**

<i>City:</i>	<i>Date:</i>
<i>Signature:</i>	
<i>Printed Name:</i>	
<i>Contacts details: Voluntary</i>	

If you would like more information about the project, you are welcome to contact our supervisor Monica Lundh from the Department of Mechanics and Maritime Sciences at Chalmers on 031772 60 61 or via e-mail [monica.lundh@chalmers.se](mailto:monica.lundh@chalmers.se).

I have taken note of the information above and choose to participate in the project. I agree that the interview is tied to analysis and recorded.

## **Appendix B** – Questions/Themes

### **CHALMERS**

1. What kind of perspective do you have about digitalization in the Engine Room/Engine Control Room?
2. What do you see as necessary skills to operate an engine room and an engine control room in the future?
3. What challenges and opportunities do you see with a future digitalization of the Engine Room/Engine Control Room?

## Appendix C – Questions/Themes

### CHALMERS

1. What kind of perspective do you have about digitalization in the Engine Room/Engine Control Room?

- What changes have you experienced in the ECR?
- How have the digitalization affected you and your working environment in the ECR?
- Are there any weaknesses with the digitalized equipment in the ECR like the monitoring equipment/ or strengths with these new monitoring?
- Why do you want or need more advanced surveillance equipment?
- Tell us what kind of development within the engine control room the company facing today?
- What is the policy within the company about digitalization?

2. What do you see as necessary skills to operate an engine room and an engine control room in the future?

- What do you think/ what are your perspective regarding your experience, how do you think the increasing presence of digitalization will affect the engineer's on board vessels operating in the ECR?
- What the increasing presence of Digitalization in the ECR what do you think about the competency/knowledge in handling these new technology.
- Do you think you have enough skills today to operate a highly digitalized ER/ECR?  
if not  
What skill do you think you are lacking ?
- Is the company currently working together with other companies or schools to develop engine control rooms of the future?

3. What challenges and opportunities do you see with a future digitalization of the Engine Room/Engine Control Room?

- How do you think the work in the engine room will change in digitalization?
- Do you see any difficulties / challenges with the digitalization in ER / ECR?
- Do you think some type of standardization is needed in ECR? (Example can be the Monitoring equipment)
- Are regulations any problem in the near future?
- What do you need from regulators and legislation societies?
- Will regulations (IMO STCW) help (or not) help with this transition?
- Do you think too much relying/trust on automation is a problem?